EVALUATION OF CARDIOVASCULAR STATUS IN PATIENTS OF DIABETES MELLITUS BY TREADMILL STRESS TESTING

THESIS

For

DOCTOR OF MEDICINE

(MEDICINE)

BUNDELKHAND UNIVERSITY
JHANSI (U. P.)
INDIA

1992

DEVENDRA KUMAR SHARMA

DEDICATED TO MY BUAJI....

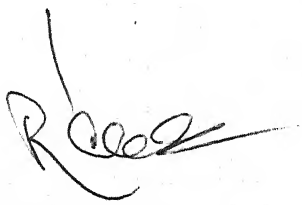
LATE Smt.SATYA VATI DEVI

C E R T I F I C A T E

This is to certify that the work entitled "EVALUATION OF CARDIOVASCULAR STATUS IN PATIENTS OF DIABETES MELLITUS BY TREADMILL STRESS TESTING" which is being submitted as thesis for M.D.(Medicine) Examination, 1992 of Bundelkhand University by Dr. Devendra Kumar Sharma, has been carried out in the department of Medicine, M.L.B. Medical College, Jhansi.

He has put in the necessary stay in the department as per university regulations.

Dated:



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The results and observations recorded were checked and verified by me from time to time.

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Dated:

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A C K N O W L E D G E M E N T S

It is not with a formal or routine gesture, but a profound sense of heartfelt gratitude and thanks giving that I acknowledge today, for all my Guide, Co-guide, Senior colleagues, friends and critics alike , because if not for them this humble work could be brought to its present finished form, today.

My head bows with obeisance and deep indept for my Guide Dr. P. Kumar, MD, D. Card., DM(Card.), Assistant Professor in Cardiology,Department of Medicine, M.L.B. Medical College, Jhansi, whose examplary dedication, uncompromising standards, and humanatarian approach finds a true reflection in my humble effort. It is indeed his unfathomed knowledge of cardiology, his untiring zest for work and a very understanding, humanatarian approach, that has affected the heart and pace of this entire endeavour. If not for you Sir, this thesis would have been an incomplete picture much lacking in your perfectionist final touches.

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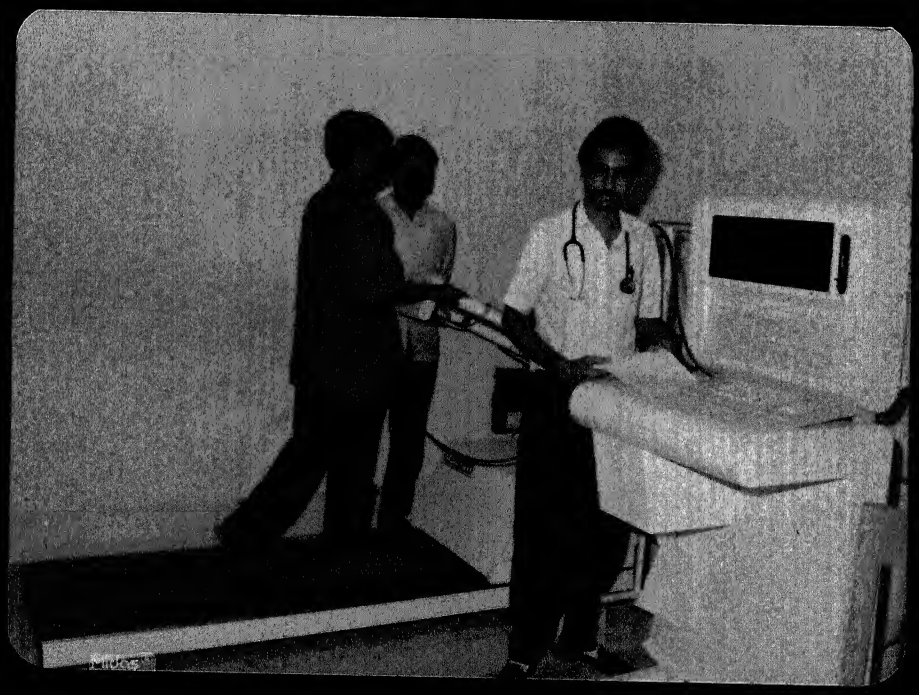
My sincere thanks to Mr. Phool Chandra Sachan who brought out this neatly typed voluminous work with utmost patience and artistic touch.

Lastly to all those co-operating and helpful volunteers, without whom this work would not have seen the light of this day.

Dated :

(Devendra Kumar Sharma)

C O N T E N T S



I N T R O D U C T I O N

INTRODUCTION

The word diabetes (to flow through) was coined by Greek physician Aeretaeus in the first century A.D.. Diabetes mellitus is a clinical syndrome characterised by hyperglycemia, due to deficiency or diminished effectiveness of insulin. Relative or absolute lack of insulin affects the metabolism of carbohydrate, protein, fat, water and electrolytes. It leads to grave consequences in the form of permanent and irreversible functional and structural changes in the cells of body, those of cardio-vascular system, being particularly susceptible. Changes also occur in eyes, kidneys and nervous system. The incidence of diabetes mellitus is one percent in western countries. It is eighth health related cause of death in United States. Nearly all morbidity from diabetes mellitus is related to cardiovascular dysfunction, either coronary artery disease or renal failure secondary to vascular disease.

The process of atherosclerosis tends to be more extensive and more severe in diabetic patients that in non diabetics resulting in an increased frequency of myocardial infarction. Indeed coronary artery disease is the leading cause of death among adult diabetics and accounts for three times as many deaths among diabetics than among nondiabetics.

The incidence of coronary artery disease correlates more closely with the duration of diabetes than its severity. In cases with long standing diabetes mellitus the size of infarct is bigger, they are more prone to develop arrhythmias and post infarction course in general is more complicated.

Laboratory testing in asymptomatic diabetics show a surprisngly high prevalence of cardiac abnormalities. Zoneraich reported ECG abnormalities in 51% and vectorcardiographic abnormalities in 75% of a group of ambulatory patients who were asymptomatic diabetics between the age of 15-81 years. Evidence of myocardial infarction was present in 14% whereas 41% had distortions of QRS vector loop, 25% of the diabetics show intra atrial conduction disturbances (Zoneraich and Zoneraich).

Coronary artery disease has been reported to show an increasing trend in India. Studies suggest that incidence of CAD ranges from 6 to 23% of all heart patients and the percentage is still higher in diabetic patients. Tne pattern of CAD as reported in India is as under.

- IHD appears a decade earlier in life as compared to the age incidence in developed countries.
- Males suffer more than the females. Ratio being 4 : 1, except the extreme of life. Low risk enjoyed by younger women in general population is lost in diabetic patients.
- Diabetes mellitus and hypertension account for about 40% of all cases.

- Heavy smoking is an important risk factor in a fair number of cases.

CAD is a condition of diverse etiologies, all having in common a disturbance of cardiac function due to an imbalance between oxygen supply and demand. The most common cause of ischemia is atherosclerotic disease of epicardial coronary arteries, which is more pronounced in diabetics as compared to non-diabetics, leading to luminal narrowing in these vessels to the extent that there is absolute decrease in myocardial perfusion in the basal state or there is lack of appropriate increase in perfusion when the demand is increased due to increased work load.

Coronary artery disease has become the most important cardiovascular event of premature death and disability. It is specially so in diabetics. The disease may result in sudden death or it may manifest itself as an acute and often fatal attack of myocardial infarction or as angina pectoris. In the diabetics these ischaemic episodes are at times painless or the pain if experienced is not as severe as in non-diabetics.

RISK FACTORS FOR DIABETES MELLITUS

Genetic predisposition.

Obesity.

Physical inactivity.

Physical and psychological stress.

Repeated pregnancies.

Birth of unusually large babies is a striking pointer to the subsequent development of diabetes in the mother.

Diabetes mellitus is major risk factors for the coronary artery disease. The others are smoking, hypertension, hyperlipidemias, obesity, physical inactivity and emotional stress, all these are reversible. The non reversible risk factors are age, male sex and genetic traits. The risk factor concept implies that a person one or more of these factors is more likely to develop a clinical coronary atherosclerotic event and is likely to do so earlier than a person with no risk factors.

DIAGNOSIS OF CAD IN DIABETICS

Postmortem studies have shown that coronary atherosclerosis often starts at an early age in diabetics and is wide spread in adults who were asymptomatic during life. In addition exercise stress test in asymptomatic persons may show evidence of silent myocardial ischemia i.e. exercise induced electrocardiographic changes not accompanied by angina and coronary angiography in such persons frequently reveals obstructive coronary artery disease. In contrast to asymptomatic phase of ischemic heart disease, the symptomatic phase presents with chest pain on account of angina pectoris or acute myocardial infarction. Once a patient has entered the symptomatic phase he may exhibit a stable or progressive course, rarely revert to asymptomatic phase or die suddenly.

Angina Pectoris : This is a clinical syndrome resulting from transient myocardial ischemia. The typical patient with angina has troublesome or frightening but occasionally only mild chest discomfort, usually described as heaviness, pressure, squeezing, smothering or chocking and only rarely as frank pain, usually in substernal and left side of chest lasting one to five minutes. Angina can radiate to left shoulder and to both arms and specially to the ulnar surface of the forearm and hand. It can also arise in or radiate to the back, neck, jaw, teeth, and epigastrium. Although angina is typically caused by exertion or emotion and is relieved by rest, it may also occur at rest and at night while the patient is in recumbent position called angina decubitus. Angina is frequently precipitated by unfamiliar task by a heavy meal or by exposu to cold. However, angina may be atypical in location and ma not be strictly related to provoking factors. Under such circumstances the exercise ECG becomes mandatory.

ELECTROCARDIOGRAM

When 12 lead ECG is recorded at rest in 70-80% of the patients with typical angina pectoris, it is found to be normal. Repolarization abnormalities i.e. ST segment and T wave changes at rest are suggestive of myocardial ischemia but they are not specific because they can also occur in pericardial, myocardial, and valvular heart

disease or with change in posture, drugs, oesophageal and biliary diseases. Due to these reasons exercise stress testing becomes most widely used test for the diagnosis of IHD.

Coronary artery disease is one fatal disease that causes recurrent chest pain. Therefore a patient who experiences such episodes of chest pain should have coronary artery disease, excluded or confirmed in order to allow for development of an appropriate management plan. Prior to the beginning of the 2nd decade of this century, the only criteria for the diagnosis of CAD were chest pain, its nature and characteristics and resting ECG. Many patients who had chest pain of non cardiac origin were diagnosed as cases of CAD and many patients who were asymptomatic but having coronary insufficiency to some extent remained undiagnosed.

Chest pain on exertion is the first symptom that forces a patient to seek advice of his physician. Earliest contribution in the field of exercise ECG was from Bousfield who recorded ST segment depression in the three standard leads for the first time during spontaneous angina in 1918. Later FEIL and Seigel (1928) demonstrated that angina was accompanied by a prolonged period of ST segment depression. They used the term positive response when ST-T wave changes were produced by exercise along with the increase of anginal pain. They considered that

ECG abnormalities in angina patients were due to reduction of blood flow to the heart and the ECG findings return to normal when chest pain subsides and also when Nitroglycerine was given to the patients with angina pectoris. They performed their exercise tests by having the patients to do sit ups. Einthoven also recorded the ST segment depression after exercise.

Dr. Arthur M Master's original and invaluable contribution in the field is truely legendry and he unquestionably deserves the credit. Master published his first paper regarding the exercise test in 1929. He measured only pulse and blood pressure to evaluate the cardiac capacity and he failed to recognize the value of electrocardiographic findings to diagnose ischemia. After 12 years of Master's original contribution, the importance of taking an electrocardiogram before and after the exercise test to detect the coronary insufficiency was first proposed by Master himself along with Jaffe.

The Master's test has a sensitivity of 48-60% and specificity of 80-83% in detection of coronary atherosclerosis but an important limitation of Master's test is that in some patients, the single work load used requires an increase in MVO_2 which is inadequate to elicit ischaemic manifestation.

Untill 1955 the Master's test was the exercise ECG test of choice and it is still widely used in many parts of the world where sophisticated and modern exercise

laboratory facilities are not available. Since 1956 modern exercise ECG test using a motor driven treadmill and bicycle ergometers began to receive wide acceptance for research purposes as well as for clinical practice. In United States of America in most medical institutions and many private clinics physicians like exercise electrocardiography performed using a motor driven treadmill. In European countries, however, the treadmill is much less popular and commonly a bicycle ergometer is used instead. The reason for this is probably the europeans are more familiar with bicycle riding as part of their day to day life.

Both bicycle ergometers and treadmill are very popular at present but treadmill has some advantages over the bicycle ergometers because maximal oxygen uptake is 6-28% higher in the former as compared to later. Moreover, ST segment changes have either been the same or slightly more frequent during treadmill testing (Wick and Sutton, 1978).

In addition to these, other forms of stress tests have also been developed such as induced hypoxia, isometric exercise and atrial pacing. These stress tests have not gained popularity owing to difficulties in performance and standardization as well as lack of sensitivity and specificity.

Various multistage exercise protocols have been developed for the graded exercise ECG test by different investigators using either motor driven treadmill or an electrically braked bicycle ergometer .

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The knowledge of diabetes dates back to centuries before Christ. Egyptian papyrus Ebers (Ca 1500 BC) described the illness associated with the passage of much urine. Celsus (30 BC to 50 AD) recognised the disease but it was not until two centuries later that another Greek physician renowned ARETAAUS of Cappadocia gave the name Diabetes (a Siphon). He made the first complete clinical description, describing it as a melting down of flesh and limbs into urine.

From 3rd to 6th centuries AD Scholars in China, Japan and India wrote of a condition with polyuria in which the urine was sweet and sticky. However, this fact was known for centuries that diabetic urine tasted sweet, it remained for WILLIS in 1674 to add the observation "as if imbued with honey and sugar". The name diabetes mellitus (mellitus = honey) was thus established. A century after Willis, Dobson demonstrated that sweetness was, indeed, due to sugar.

The progress in understanding of this disorder came very slowly until the middle of 19th century. Gangrene had been described by Avicenna, an Arab physician, in about 1000 AD. Its hereditary tendency was described (Passed with seeds) as well as two general varieties one with the classic acute symptoms (type I or IDDM of today's terminology) and other with "torpor,

indolence and corpulence" (Type II or NIDDM).

The islets in the exocrine pancreas were first noted in fish by Brockman early in 19th century, but Langerhans, in 1869, first described them in mammals. Soon aftet this, German scientist, Von Mering and Minkowski found that surgical removal of pancreas produced diabetes in dogs.

In 1921 Frederick Banting and Charles best prepared active extracts of pancreas which lowered the elevated glucose levels of diabetic dogs.

The clinical recognition of coronary artery disease begins with awareness of marked frequency of this complication, when a patient gives history of typical angina pectoris. Anatomically severe coronary atherosclerotic disease will be confirmed in more than 90% of instances. The diabetic may also present with vague and atypical chest, neck, or upper extremity pain, or Epigastric discomfort. A wide variety of symptoms may be anginal equivalents. The fatigue particularly when produced abruptly by exercise and relieved by rest may signal ischaemic heart disease.

The significance of exercise ECG test in diabetics is further increased because of higher incidence and atypical presentation or even absence of alarming symptoms inspite of myocardial infarction.

The work on exercise ECG and recognition of its importance dates back to early part of the century in 1918 and the credit goes to Bonsfield.

Dr. Arther M master will be remembered for his contribution in the field of exercise ECG. The Master's test is a single lead stress test in which the subjects perform preselected number of trips, up and down two nine-inch steps in a prescribed time period with recording of leads II and V_3 through V_5 at intervals after exercise. The original 90 second test has been extended to 3 minutes (The double master's) and the number of trips further increased by 15% (The augmented double master's test). While a variety of changes in the electrogram have been proposed as indicators of ischaemia, only the occurrence of a flat ST depression of at least 0.05 mv in magnitude has been widely accepted and validated for master's test. Studies correlating electrocardiographic response to the Master's test with coronary angiography suggest that the test has a sensitivity of 46-66% and specificity of 80-83% in detecting the obstructive coronary artery disease.

In 1931 Wood and Wolferth also described the ST segment change following exercise in patients of CAD. They described that V_4 was the most useful lead to detect the ischaemic changes than the standard limb leads.

Goldhammer and Scherf in 1932 reported ST segment depression after exercise in 75% of 40 patients with Angina and they documented the value of exercise to confirm the diagnosis of ischemia due to coronary heart disease.

Ketz and Landt in 1935 proposed that lead V_5 was the best lead to bring out the ischaemic changes.. They asked their patients to exercise by lifting dumbbells while lying on a table.

In 1940, Riseman and co-workers described the use of continuous monitoring for the first time and they pointed out that ST segment depression usually appeared before the onset of anginal pain and usually persisted for a time after the chest pain subsided.

Leibow and Feil in 1941 recognised for the first time the false positive ECG due to digitalis effect.

Johnson and co-workers in 1942 developed Harward step test which was very similar to the original Master's test. It was used widely in athletic circles to assess physical fitness.

Wood and co-workers in 1950 described their experience with an effort test at the National heart Hospital in London. They asked their patients to run to the maximal level of their capacity. They concluded that sensitivity of their test was 88%, reliable as compared to 39% reliability of Master's test. They further emphasized that the amount of exercise should not be fixed but rather adjusted to the patient's capacity in order to bring out a higher percentage of positive tests in patients with coronary artery disease by giving the maximal exercise.

Yu and Soffer in 1932 proposed the following

ECG changes indicating myocardial ischaemia by using the Master's test with continuous monitoring.

A. ST segment depression of 1.0 mm or greater.

B. Alteration of the T wave direction from upright to inverted or inverted to upright.

C. 50% or greater increase in T wave amplitude as compared to resting.

D. Prolongation of the Q-T : T-Q ratio to more than two, during exercise.

They again stressed the importance of continuous monitoring. In addition Yu and co-workers reported the exercise ECG test using a motor driven treadmill elevated to a 10% to 20 % grade with continuous monitoring. They proposed a bipolar lead from the right scapular to the lead V_5 position to be used for treadmill exercise ECG test.

Fiel and Brofman in 1953 studied the effect of exercise on electrocardiogram in bundle branch block and also reported false positive exercise ECG tests in his patients with W.P.W. syndrome.

Abenavoli reported ischaemic ECG abnormalities in seven of twelve asymptomatic diabetic males undergoing exercise testing.

PATHOPHYSIOLOGY OF EXERCISE

The basic aim of exercise testing is to increase the myocardial oxygen requirements to unmask a reduced,

relatively fixed coronary blood flow. The resultant myocardial ischaemia may then be detected through electrocardiographic abnormalities, usually in the form of ST segment changes. The exercise ECG has two major roles, one is to determine whether the coronary circulation is capable of increasing the oxygen supply to the myocardium in response to increased demands. During physical exercise, myocardial oxygen demand is increased by increment of systolic blood pressure, the contractile state of the myocardium and the heart rate. The other role of exercise ECG test is to assess the exercise capacity.

Augmentation and redistribution of cardiac output, as well as increased tissue extraction of oxygen from blood, are important mechanisms for increasing oxygen transport and delivery during exercise. Cardiac output increases during exercise in a linear relation to the total body oxygen consumption until the subject exceeds 40% of maximal oxygen consumption at which the relation becomes curvilinear. This augmentation of cardiac output is accomplished by increase in heart rate, myocardial contractility and stroke volume and is associated with a rise in central blood pressure and a fall in vascular resistance.

The decrease in total peripheral vascular resistance results from marked local vasodilatation in exercising muscles, a response, which overcomes the

opposing effects of a generalised increase in activity of sympathetic noradrenergic fibres to both resistance and capacitance vessels. It is supposed that blood flow to the cardiac and active skeletal muscles increases while vasoconstriction occurs in inactive muscles and in the visceral vascular beds.

In comparing the mechanism responsible for augmenting oxygen delivery to cardiac versus skeletal muscles, two important differences exist. First, myocardium depends almost entirely upon increases in coronary arterial blood flow, for oxygen extraction is nearly complete, about 7% even at rest, with coronary sinus blood containing only 2 to 5 volumes percent of oxygen. It indicates that myocardium is a flow dependent tissue. Skeletal muscles on the other hand, are capable of three fold increase in oxygen extraction above resting volumes. Second skeletal muscle is able to continue contracting in the absence of oxygen, whereas cardiac muscle is strictly aerobic. Coronary blood flow is largely diastolic. During exercise a fall in coronary vascular resistance accounts for the increase in coronary blood flow despite a decrease in diastolic time per minute. The fall in the coronary resistance may be mediated by an increase in myocardial release of adenosine, a potent coronary vasodilator, in response to hypoxia or to an increase in oxygen consumption per se.

The type of exercise is another important consideration when evaluating a subject's response to stress testing. The circulatory response to exercise will depend on whether the exercise is conducted in upright or supine position, whether it is dynamic or isometric, whether is is performed with the upper or lower extremities or whether it is executed on a bicycle ergometer, steps or treadmill.

There is only small difference in maximal cardiac out put and oxygen consumption when bicycle, treadmill or step exercise are compared. Cycling elicits the lowest maximal levels and running on a treadmill elicits the highest. The difference is hardly seven per cent. Bicycle exercise may be inherently more stressfull than treadmill exercise, since the former evoked higher heart rates and blood pressure at the same work load. It could be related to the discomfort associated with the bicycle seat.

The coronary blood flow during exercise is significantly reduced when there is at least 50% narrowing of the coronary blood vessels although a significance reduction at rest occurs only when the stenosis is 85% . The product of heart rate and systolic blood pressure (Double product) can be calculated and this is considered to be a practical index for myocardial oxygen requirement.

PROTOCOLS FOR TREADMILL ECG TEST

Although numerous multistage protocols for exercise have been designed by different investigators, none of these protocols are ideal for every individual. As far as the ideal exercise ECG test is concerned, the initial work load should be well within the individual's anticipated physical working capacity. The work load should be increased gradually and not abruptly and it should be maintained long enough to attain a near physiologic steady state. It is essential to look for the symptoms and signs, like chest pain, dizziness, dyspnoea, extreme fatigue, blood pressure, heart rate, and electrocardiographic changes during the entire procedure and throughout at least six to eight minutes of post exercise period. The exercise should be terminated when significantly abnormal symptoms, signs, marked ST segment changes or serious arrhythmias are appreciated or when a predetermined heart rate is reached. In same exercise protocols the work load is increased by changing speed alone with fixed grade whereas in others grade is increased with fixed speed. In Bruce protocol however, the work load is increased by changing both speed and grade. If we compare Balke, Bruce, Ellestad and modified Astrand protocols, there is hardly any significant difference in oxygen uptake, heart rate, and blood pressure, when exercise is done accordingly to these protocols.

For progressive increment of work load at least three minutes' intervals are preferable so that steady state blood pressure and heart rate responses can be achieved. If the speed becomes such that the patient has to run or jog in order to keep up the speed, this results in an undesirable deterioration of electrocardiogram in addition to giving an uncomfortable feeling to the patient.

When maximal exercise test is compared with the submaximal(85-90% of the maximal heart rate) there appears to be no significant difference in clinical and practical sense. Many authors prefer submaximal exercise test because many patients with coronary heart disease are unable to perform the exercise test upto maximum limit. The exercise test should not be too short. Not to allow sufficient time for the patient to warm up or too long, so that it does not limit exercise by fatigue rather than angina.

Name of protocol	Stage	Duration (min.)	Grade (%)	Speed	METS
Bruce	1	3	10	1.7	4
	2	3	12	2.5	6-7
	3	3	14	3.4	8-9
	4	3	16	4.2	15-16
	5	3	18	5.0	21
	6	3	20	5.5	-
Modified Bruce	0	3	0	1.7	1.5
	1	3	5	2.8	2.5
	2	3	10	2.8	5.0
	3	3	12	4.1	7.0
	4	3	14	5.5	10.0
	5	3	16	6.7	13.0
	6	3	18	8.0	16.0
	7	3	20	8.8	19.0
	RE	5	0	1.7	-

The percentage of maximal predicted heart rate that a patient achieves at peak exercise can provide an estimate of efficacy of the test. The percentage of maximum heart rate at which symptoms or electrocardiographic changes occur may be helpful in assessing a person's degree of disability.

The metabolic equivalents (MET) which are multiples of basal metabolic rates are commonly used to express the work load in various stages of exercise protocols. The resting oxygen consumption is approximately 3.5 ml/kg/min. or 1 MET. If a subject is tested to his maximum physiologic capacity, he is presumed to have reached his maximum oxygen consumption (Max. VO_2). Each level of work on the treadmill requires a specific oxygen consumption per kg of body weight i.e. a specific multiple of resting oxygen consumption, can be 2 METS, 3 METS, X METS, therefore, it is known what number of METs are required for each stage of a particular protocol. The total number of METs achieved can be used as an indicator of work capacity. If we correlate the cardiovascular capacity with METs the functional class III patients usually becomes symptom limited at 3-4 METs. Functional class II patients become symptom limited at 5 or 6 METs. and functional class I patient can perform exercise beyond 7 or 8 METs. Healthy active man can perform exercise upto 12-15 METs. Athelets can perform exercise upto 16 to 21 METs.

LEAD SYSTEM

The most commonly utilized lead system is a modified bipolar lead V_5 when single channel ECG recording equipment is available. The positive electrode is placed in the fifth intercostal space at left anterior axillary line and the negative electrode is placed in various locations, including the forehead(CH_5), right infraclavicular region (CS_5), left fifth intercostal space (CC_5), or the back (CA_5) manubrium (CM_5). Among these combinations, CM_5 seems to be most popular lead system and this lead is reported to detect 89% of ECG abnormalities to compare with 12 lead ECG recordings. Blackburn reported CM_5 to be more sensitive in detecting ST segment shift but at the same time the incidence of false positive test is also increased owing to its semivertical orientation.

When the two channel recordings are available, an additional inferior lead (II,III or avF) with a modified lead V_5 can increase the diagnostic yield of exercise ECG tests. When a multichannel recorder is available, six leads consisting of leads II, avF and V_3, V_4, V_5 and V_6 are said to be ideal to detect more ECG abnormalities. When limb leads are utilized in order to prevent motion artifacts, arm electrodes should be placed in both infraclavicular fossae and the left leg electrodes should be placed just above the anterior superior iliac spine.

FRANK X, Y, Z leads also used some time are less sensitive in detecting exercise induced ST segment

shanges and this lead system has not been widely accepted.

In most of the institutions now 12 lead ECG recording is done before, during exercise and during recovery period with simultaneous 3 leads recording for continuous monitoring.

CLINICAL USES OF TREADMILL EXERCISE TEST

1. Evaluation of chest pain.
   A. In patients with stable effort angina.
   B. In patients with atypical chest pain of probable ischemic origin.
   C. In patients with atypical chest pain of probable nonischemic origin.
2. Assessment of effort tolerance.
   A. In asymptomatic subjects.
   B. In patients with known ischemic heart disease.
   C. In patients with known nonischemic heart disease (e.g. valvular heart disease).
3. Detection of myocardial ischemia in patients at high risk for coronary artery disease.
4. Detection of supraventricular and/or ventricular dysrrhythmias.
   A. In patients with effort related lightheadedness Breathlessness, or frank syncope.
   B. In association with myocardial ischemia.
5. Evaluation of exercise blood pressure in hypertensive patients.

6. Evaluation of antianginal therapy.
   A. Medications.
   B. Myocardial revascularisation procedures.
7. Development of guidelines for exercise prescription and prognosis in post-myocardial infarction patients.
8. Use in sports medicine and corporate heath screening.

EVALUATION OF PATIENTS WITH CHEST PAIN

The reason to perform treadmill exercise test in patients with undiagnosed chest pain is to acquire a data base consisting of both ECG and non ECG exercise responses. This data base then allows the clinician to form a firmer diagnostic impression as to whether or not CAD is present.

The ECG ST segment response on exercise has received a great deal of attention as a prognostic marker for coronary artery disease for over two decades. Only recently have hemodynamic responses been acknowledged as being equally meaningful. Important non-ECG exercise responses that should be included in the data base are :

1. Heart rate achieved at peak exercise.
2. Systolic and diastolic blood pressure responses at submaximal and maximal exercise.
3. Peak rate pressure product (systolic blood pressure x heart rate) as a non invasively determined reflection of myocardial oxygen consumption (MVO_2).
4. Duration of exercise.

5. Time of onset of anginal symptoms/ischemic changes during exercise as well as the duration of ischaemic changes in ECG (if any) in the recovery period.
6. Development and characterisation of dysrhythmias specially ventricular.
7. Development and nature of clinical symptomatology, specially anginal pain or symptoms of inadequate cardiac output such as dizziness, staggering gait or marked breathlessness.

NORMAL RESPONSE TO EXERCISE

1. Progressive increment of blood pressure and heart rate during exercise.
2. Shortenning of Q-T interval with increased Q-T:R-R ratio.
3. Physiological S-T segment alteration :
   a. Junctional (J. point) S-T segment depression or 2 mm with duration $\angle$0.06 sec.
   b. Vasoregulatory asthenia.
   c. Orthostatic ECG changes.
   d. Labile T wave changes.
   e. S-T segment depression only in the post exercise period (?).
4. Alteration of T wave direction or morphology.
5. Slight reduction of R wave amplitude.
6. Shortening of P-R interval or varying P-R intervals.

7. Downward displacement of P-R segment due to prominent T-a wave amplitude.
8. Peaking and tall P wave during very rapid heart rate.
9. Minor symptoms such as dyspnoea , fatigue, sweating etc.

INTERPRETATION OF THE EXERCISE ECG TEST

The ECG S-T segment response had received a great deal of attention as a prognostic marker for coronary artery disease for over two decades. Only recently have hemodynamic responses been acknowledged as being equally meaningful.

Among various S-T segment alterations the horizontal or downsloping S-T segment depression of 1 mm or greater is the most reliable criterion for the positive exercise ECG test. Upsloping (slow rising) S-T segment depression is an almost equally reliable finding for the positive exercise ECG test. The S-T segment elevation is only occasionally observed and in most cases, it is found in patients with previous myocardial infarction.

Various types of S-T segment responses to exercise are :

1. S-T segment depression.
   a. Horizontal (square wave)
   b. Functional (junctional or j point).
   c. Downsloping.
   d. Upsloping
   e. Slow rising
   f. Sagging.
2. S-T segment elevation.
   a. Horizontal
   b. Upsloping.

HORIZONTAL AND DOWNSLOPING S-T SEGMENT DEPRESSION

For maximal (and most submaximal) exercise tests, ischemic S-T segment depression of 1.0 mm or more at 90 m sec after the j point, 'in association with a horizontal or downsloping S-T segment,' is required to call a test positive. Using this criteria, the incidence of true positive responses in patients with coronary artery disease has varied from 60 to 85%(sensitivity). Goldschlager et al (1976) reported that 330 patients were referred for diagnostic evaluation of chest pain with or without prior infarction, and had both maximal treadmill exercise testing and selective coronary angiography. Depending upon the criterion for an ischaemic response, sensitivity of S-T segment changes was 64% to 76% and specificity was 83 to 93%. Downsloping S-T depression was associated with only 1% false positive, while horizontal depression was associated with a 15% false positive rate. However, if time of onset (first 3 minutes in Bruce protocol) and slow recovery (ST depression persisting for $\bar{7}$ 8 minutes from exercise termination) were considered, there was a 91%, 86% and 90% prevalence of two vessel , three vessel or left main coronary disease respectively.

The concept that marked S-T segment depression is associated with a more severe degree of coronary artery narrowing than minimal changes has been demonstrated by a number of investigators. Table I compiles the results of four studies in which the amount of ischaemic depression is

compared with the incidence and extent of coronary occlusive disease. This table indicates that patients in whom 2 mm or greater ischemic S-T depression occurs have a 57% incidence of three vessel disease and an overall 85% incidence of two or three vessel disease. The incidence of single vessel disease in patients having 2 mm or more S-T depression is only 17%.

TABLE I

S-T depression	Single vessel (%)	Double vessel (%)	Triple vessel (%)
⩾2 mm	17	28	57
1.0-1.9 mm	21	30	42
⩽1.0 mm	19	16	21

When S-T segment deviation is analysed, a number of variables must be considered, one of which is clinical setting (whether the individual has angina, atypical chest pain, or no cardiovascular symptoms) in which testing is performed. Koppes et al (1977) popularised this concept by comparing the prevalence of coronary disease and test diagnostically (utilising the concept of Bay's theorem and likelihood ratio) to help and put in perspective what it means to have an ischaemic S-T response during or after exercise. Patients with a classical history of angina will be found to have coronary artery disease 90% of the times while asymptomatic individuals, depending on age, might have a prevalence of coronary artery disease of 10% or even less.

Approximately 50% of patients with atypical angina will be found to have coronary disease.

The likelihood ratio relates sensitivity and specificity and weighs the diagnosticity of an abnormal and normal test. Using average figures for exercise testing of 70% sensitivity and 90% specificity, the likelihood ratios of an abnormal and normal test are :

$$\text{Likelihood ratio (abnormal test)} = \frac{\text{Sensitivity}}{\text{1-specificity}} = \frac{0.70}{0.10} = 7$$

$$\text{Likelihood ratio (Normal test)} = \frac{\text{Specificity}}{\text{1-sensitivity}} = \frac{0.90}{0.30} = 3$$

The patients with atypical angina, in general has a 50% chance of having angiographic coronary disease. But, with an ischemic exercise response, this probability increases to 88%, while a normal treadmill test reduces it to 25%. In the asymptomatic subjects, a negative exercise test reduces the probability of an individual having coronary disease to 4%, while an ischemic S-T response increase the probability to 44%.

TABLE II

Clinical presentation	Pre-test odds/ Prob.	Positive test post test odds/Prob.	Positive test post test Odds/Prob.
Typical Angina	9:1/90%	63:1/98%	9:3/75%
Atypical Angina	1:1/50%	7:1/88%	1:3/25%
Asymptomatic	1:9/10%	7:9/44%	1:27/4%

Although these concepts are theoretical, they do serve as a guidelines for assessing S-T change with exercise Coronary lesions, considered critical on an anatomic basis, consist of left main and left main equivalent (proximal left anterior descending and circumflex lesions), triple vessel, and proximal left anterior descending disease. There is some evidence that exercise testing may help to identify patients with these critical lesions by finding markedly positive test.

TREADMILL TEST RESPONSES CONSIDERED TO HAVE PREDICTIVE IMPORTANCE FOR ARTERIOGRAPHICALLY DOCUMENTED SEVERE, MULTI-VESSEL AND/OR LEFT MAIN CORONARY ARTERY DISEASE.

ELECTROCARDIOGRAPHIC CRITERIA

- S-T segment response :
  . Down sloping.
  . Elevation (in the absence of myocardial infarction).
- S-T segment depression exceeding 2 mm.
- Serious ventricular dysrhythmias occurring at low (120-130/minutes) heart rate.
- Early onset (first 3 minutes) of ischemic S-T segment depression or elevation.
- Prolonged duration ($\bar{7}$6 minutes) in the post exercise recovery period of ischemic S-T segment depression.

NON-ELECTROCARDIOGRAPHIC CRITERIA

- Low achieved heart rate ($\leq$ 120/minute).
- Hypotension ($\leq$10 mm Hg rise in systolic pressure at any time during the test).

- Rise in diastolic blood pressure(⁄110-120 mm Hg).
- Low achieved rate pressure product (⁄15,000).
- Inability to exercise beyond 3 minutes.

Table III describes the S-T segment response of individuals with known left main coronary disease. In three studies 100% of patients had S-T segment depression equal to or greater than 2 mm. In contrast, Ellestad found only 67% of such patients with 2mm or more S-T depression and 20% with negative tests. In a study of 57 patients with greater than 50% left main obstruction Salem et al (1978) found that 89% had ischemic S-T depression and in 70% the S-T depression was greater than 2 mm. Furthermore, of 23 patients with left main obstruction greater than 75%, 19(83%) had greater than 2 mm S-T depression.

TABLE III

Incidence (%) of 2 mm or greater S-T depression in subjects with left main or left main equivalent disease from five studies.

Kleiner et al (1976)	100%
Cheitlin et al (1975)	100%
Levitas et al (1976)	100%
Ellestad et al (1975)	67%
Salem et al (1978)	70%

As important as the degree of S-T depression is the time of onset of ischemic electrocardiographic changes and the workload and heart rate at which these occur.

Functional (J. point) depression is a frequent ECG finding during graded exercise testing and is often

a precursor to horizontal or downsloping S-T segment experimentally, Case et al (1969) demonstrated that in early myocardial ischemia, the onset of anaerobic metabolism is manifested first by J. point depression and is followed later by S-T depression. When the S-T response is limited to J. point depression, it is generally interpreted as normal finding. Mattingly et al(1957) found increased mortality rates in a group with J. point depression when compared with a group without J point depression, but a lesser mortality than in those who manifested horizontal or downsloping S-T depression.

Kurita et al (1977) evaluated the relationship of isolated junction S-T depression, induced during treadmill exercise testing, with coronary angiographic findings in 230 patients. Of 75 patients with junctional depression of less than 1.5 mm, only 10 had 50% or greater stenosis of at least one major coronary artery (predictive value of a negative test is 87%). It is noteworthy that only two patients had multivessel disease. 42 patients had junctional depression of 1.5 mm or more. Of these, 23 had significant stenosis (predictive accuracy of 55%) and 12 of that group had multivessel disease.

Aside from the depth of junctional S-T depression, attention to the S-T slope may prove important in improving sensitivity, specificity and predictive value of the test. Stuart and Ellestad (1976) followed 438 patients for a year and found a similar mortality in 230 subjects with 2 mm

horizontal depression, as compared with 124 subjects with a slowly upsloping S-T segment (defined as 2 mm or more depression 80 m sec after the J point). These two groups also had the same incidence of two or three vessel disease. Kurita et al (1977) found that 94% of 35 patients with this type of response (slowly upsloping S-T segment depression) had coronary occlusion of 50% or more and 60% had multivessel disease. In others' views, the slowly upsloping S-T segment and J point depression though are abnormal responses, but are not as good as indicator of CAD (lower predictive value) as are horizontal and downsloping S-T depression.

Exercise S-T elevation has been reported rarely in individuals, apparently free of ischemic heart disease, but more commonly, it is associated with severe localised coronary artery obstruction or with left ventricular aneurysm.

Allmami and Ellestad's (1972) patients with exercise S-T elevation had angiographic and/or clinical evidence of left ventricular aneurysm. However, over half of their patients with angiographically documented aneurysm did not develop S-T elevation. The failure to produce S-T elevation in the presence of known ventricular aneurysm may, therefore, indicate additional ischaemia, and the absence of S-T depression in an individual with known coronary disease may raise the suspicion of an underlying ventricular aneurysm.

Chahine and co-workers (1976) reported a 86% incidence of left ventricular dyskinesis or aneurysm in their patients who developed S-T elevation with exercise. They too

felt, that exercise S-T elevation is related more to the wall motion abnormality than to myocardial ischemia, per se.

In contrast, Fortium and Friesinger and Heege et al (1970) reported that exercise S-T elevation was a manifestation of severe myocardial ischemia. Streuss and co-workers (1975) supported the theory that in the absence of previous myocardial infarction, severe ischemia alone can produce S-T segment elevation. A theory classifying the aneurysm-versus-ischemia controversy was presented by Haist. It was his opinion that S-T elevation was likely to result from a wall motion abnormality, whenever it occurred in the absence of reciprocal S-T segment depression and remained localised to ECG leads subtending the infarcted area. In contrast, he felt that S-T elevation was more likely to result from left ventricular dysfunction and/or myocardial ischemia when reciprocal S-T depression was present.

The leads in which S-T segment depression occur are poor predictors of the anatomic location of myocardial ischemia. However, S-T segment elevation seems to be a fairly good localizer of the site of coronary stenosis (Ekmekci et al, 1961).

R WAVE AMPLITUDE (RWA)

Brody demonstrated in 1956 that because of the radial orientation of left ventricular electromechanical forces, R wave amplitude was proportional to left ventricular volume. Monoach et al (1971) confirmed the Brody

hypothesis in 1971. With the Brody hypothesis, it might be reasoned that exercise in normal subjects could result in an increase in stroke volume, resulting in a decrease left ventricular volume and a decrease in R wave amplitude. In contrast, subjects with coronary artery disease particularly those with impaired left ventricular function, might show the opposite effect.

Bororis et al (1978) undertook several studies to assess the value of R wave amplitude changes during treadmill testing. They found that the group of patients with decreased RWA after exercise had less severe coronary artery disease and fewer wall motion abnormalities. With the condition of RWA assessment, the overal sensitivity was increased from 48 to 63%, and specificity from 59 to 79%. Oillespie et al (1978) studied 75 subjects with bicycle ergometry and coronary angiography. They found that the sensitivity for S-T change alone was 64%. The heart rate at which RWA changes occur may also be a consideration. Greenberg and Ellestad (1979) alluded to some preliminary information that would suggest that in normals the R wave increases until the patient reaches a heart rate of 120-130, at which point it begins to decrease, suggesting that measurements would have less significance in patients who stop early in the protocol before their heart rates reach a significant level.

T WAVE VECTOR

Aravindaksnan et al (1977) evaluated the results of submaximal exercise tests in two groups of patients with T wave abnormalities. Group I consisted of patients with documented ischemic heart disease and group II consisted 28 individuals in whom ischemic heart disease appeared unlikely. T wave normalization occurred frequently in both groups and was unrelated to changes in the S-T segment. S-T segment changes occurred in 88% of the patients with ischemic diseases and in only 4% of group II subjects indicating that the S-T segment response to exercise was not influenced by the T wave vector. Thus, T wave normalization is thought to be independent of S-T segment changes and does not increase the incidence of false negative response in individuals with ischemic disease or false positive responses in individuals without disease. The appearance of isolated T wave inversion is of no diagnostic significance as it is commonly seen in patients without disease.

U WAVE

Exercise induced U wave inversion in patients with a normal resting ECG and in the absence of left ventricular hypertrophy strongly suggest myocardial ischemia. This ECG repolarization phenomenon may occur in the absence of S-T segment abnormalities and is usually

indicative of a significant stenosis of the left anterior descending coronary artery. The U wave inversion is difficult to detect during exercise especially at high heart rates, and often becomes apparent in the immediate recovery period when the heart rate is slowing.

VENTRICULAR ARRHYTHMIAS

Most studies have shown a greater incidence of exercise induced ventricular dysrhythmias in patients with CAD compared with normal subjects. Exercise related ventricular arrhytnmias occur in 11% to 40% of normal and 20% to 72% of individual with coronary artery disease, thus limiting the usefulness of this variable in distinguishing those with and without coronary disease. The occurrence of complex ventricular arrhytmia as multifocal and too frequent VPC's coupletes, Ron T phenomenon and ventricular tachycardia with exercise has been said to be associated more often with coronary disease than without. Mc Henry et al (1976) observed exercise induced ventricular tachycardia only in subject with coronary disease.

Some investigators have indicated that the occurrence of S-T segment changes or exercise induced chest pain and ventricular ectopics result in a greater predictive value for multivessel disease and might also be an indicator for a grave prognosis. Helfant et al (1974) studied 20 patients with coronary disease, a 2 mm or greater S-T depression, and exercise induced VPB's.

Twelve of the group had triple vessel disease and six had double vessel disease. Anderson et al (1972) found no improvement in predictive value of the exercise test when dysrnythmias in conjunction with the S-T segment changes were utilised in the determination of a positive test.

Another feature relating exercise induced VPBS and coronary disease and multi vessel disease is the occurrence of arrnythmia at low heart rates during exercise. Mc Henry et al (1976) observed that in patients with coronary disease, VPBs were much more likely to appear at heart rates below 150 beats per minutes. In a follow up study of 197 symptomatic patients with angiographically proved CAD. Mc Henry et al found that 53 of 57 patients who demonstrated exercise induced ventricular arrhythmia did so at a heart rate of 130 beats per minute or less.

The occurrence of ventricular arrhythmias with exercise has been attributed to increased sympathetic tone, increased myocardial oxygen demand, or a combination of the two. Ventricular premature beats, particularly early cycle VPBs, ventricular tachycardia, ventricular fibrillation are consistently found at the inception of acute myocardial ischemia. In the patients with CAD, exercise may induce ischemic changes, thereby provoking ventricular arrhythmias and indeed this experimental evidence is used to support the theory that exercise induced ventricular ectopy may represent an 'ischemic equivalent'.

NON ECG RESPONSES

ANGINA

The significance of angina during stress testing has been evaluated by Weiner et al (1976) who reviewed the records of 281 patients undergoing coronary angiography and exercise testing and grouped them according to whether they had ischemic S-T segment changes and / or anginal chest pain during exercise testing.

TABLE IV

Comparison of exercise S-T depression and exercise angina in the diagnosis of CAD multivessel disease (MVC).

	Number	Angigraphic CAD(%)	MVD (%)
+ ECG + EA	76	91	93
+ ECG - EA	85	65	76 76
- ECG + EA	40	72	72
- ECG - EA	80	35	60

Indeed, the probability of coronary disease is the same whether exercise induced angina occurs without ischemic S-T changes or S-T changes occur without angina.

Cole and Ellestad (1978) also assessed the significance of chest pain during treadmill exercise and found that coronary events were twice as frequent in subjects with angina and S-T segment depression as in those with S-T depression alone. The incidence of coronary events was more than twice as great when the angina was

induced by light work load (4 METS). Additionally, if the occurrence of angina during exercise testing was utilized as a positive test, the sensitivity for angiographic coronary disease increased from 64% (when ischemic S-T changes were the only criterion for positivity) to 85% when angina occurred during testing.

It has been amply demonstrated that true angina is fairly reproducible in a given person at the same heart rate blood pressure, product (Double product). Thus, if chest pain is reproduced at the same double product, it is likely to an angina.

ADEQUATE HEART RATE RESPONSE

Chronotropic incompetence is a term coined by Ellestad and Evan. They defined chronotropic incompetence as any heart rate response below the 95% confidence limits of their protocol, adjusted for age and sex. In following a group of individuals with this abnormal heart rate response, they observed some coronary event in 15% per year. Although it is difficult to generalize expected heart rates for given work load because of the many variables involved, a general rule is that the heart rate should increase in the order of five to ten beats per minute per MET. The limits of chronotropic incompetence remain difficult to define, owing to many variables involved, in its most advanced form (failure of heart rate to increase at all or when small heart rate increases are associated with other

manifestation of left ventricular impairment or severe coronary disease .e.g. hypotension or S_3 gallop), chronotropic incompetence is probably a good indicator of severe left ventricular disease.

INADEQUATE BLOOD PRESSURE RESPONSE

The expected blood pressure response to exercise is an incremental rise in systolic pressure, with no change or a slight fall in diastolic pressure, a phenomenon repeatedly documented despite the inaccuracies inherent in recording cuff blood pressure (particularly diastolic pressure) during exercise. Several studies have demonstrated a mean systolic pressure increase of 7.5 mm Hg per MET (range 5-12). The amount of increase is age related and is more marked in older age groups.

A small but significant number of patients undergoing treadmill exercise develops hypotension either as an isolated abnormal finding or associated with S-T segment depression and/or angina. Recognition of this hypotensive response is important not only for the safe conduct of the test, but because the value of this sign as a predictor of critical narrowing of the coronary arteries has been suggested by a number of reports.

ABNORMAL EXERCISE BLOOD PRESSURE (Ab BP)

TABLE V

Sensitivity and specificity for left main disease and triple vessel disease.

Study	No.	Sensitivity (%)	Specificity (%)
Thompson et al	15	93	-
Morris et al	25	60	99
Pontius et al	72	54	90

Usually, exertional hypotension is accompanied by other indicators of severe coronary disease, such as early marked S-T depression or chronotropic incompetence.

OTHER CRITERIA

Less than 10 mm Hg increase in systolic blood pressure, failure to achieve a peak systolic pressure of 140 mm Hg during exercise.

FALSE POSITIVE AND FALSE NEGATIVE ECG EXERCISE TEST

Recognition of causes of "False Positive" ECG S-T segment alterations during exercise is of utmost importance in order to avoid misinterpreting an abnormal test. Ischemic appearing ST-T wave abnormalities occurring during hyperventilation may lead to a mistaken diagnosis of exercise induced myocardial ischemia due to coronary disease. Such ST-T changes occur in 2 to 4% of patients undergoing treadmill testing, with a particularly high prevalence in women with mitral valve prolapse. Patients having hyperventilation induced S-T abnormalities, who develop similar

abnormalities during exercise should not be considered having coronary artery disease (unless the pretest probability of disease was high). A second large category of patients in whom "False positive" ECG S-T segment abnormalities occur are those in whom left ventricular depolarization and thus also repolarisation, is abnormal. This group consists of patients with left ventricular hypertrophy, left sided intraventricular conduction delay, and Wolf-Parkinson-White (WPW) syndrome. The exercise ECG is unreliable in patients receiving digitalis unless the S-T segment response is perfectly normal when the test can be labelled negative with certainity. Patients who have abnormal ECGs at rest have been reported to show a false positive exercise test over 50% of the time, an observation that probably reflects insufficiently rigorous ECG criteria for the diagnosis of ischemia. Patients with vaso-regulatory abnormalities who often manifest tachycardia, abnormal supine and/or standing blood pressures, the labile ST-T wave that change with body position and hyperventilation, may have markedly abnormal stress ECGs even without CAD. S-T segment response normalizes with continued exercise in these individuals.

OTHER FACTORS WHICH MAY CAUSE A FALSE POSITIVE EXERCISE ECG TEST

Drugs : Digitalis, Diuretics, antidepressant drugs, sedatives and estrogen.

Cardiac disorders: Cardiomyopathy, myocarditis, Pericarditis, Rheumatic heart disease, Hypertensive heart disease.

Hypokalemia:

FACTORS WHICH MAY CAUSE FALSE NEGATIVE EXERCISE ECG TEST

Drugs : Propranolol, Nitroglycerine, and other antianginal drugs, Procainamide, Quinidine, Phenothiazine.

Coronary heart disease : Old myocardial infarction(due to cancellation of opposing vector), proven angina pectoris (especially single vessel disease).

Inadequate exercise :

Left axis deviation, left anterior hemiblock :

MULTIVARIATE INTERPRETATION OF STRESS TEST

Recently attempts have been made to improve the diagnostic accuracy of the treadmill test by employing the techniques of multivariate analysis. Such variables, alone and/or in combination might include age, sex, cholesterol, HDL, exercise induced angina, specific ECG S-T segment criteria for ischemia and the time of their occurrence, blood pressure response, achieved heart rate, double product at peak exercise, exercise duration, symptoms, character of arrhythmia, R wave amplitude and many others. This approach has focussed the clinicians' attention to the total exercise response rather than just the electrocardiographic changes in the evaluation of patient with chest pain.

A I M S O F S T U D Y

AIMS OF STUDY

1. To find out the incidence of cardiovascular involvement in the form of I.H.D. in patients of Diabetes Mellitus.

2. Evaluation of chest pain :

   a. In those diabetic patients who have effort angina.

   b. In those who have atypical chest pain which is probably of ischemic origin.

   c. In those who have atypical chest pain which is probably of non-ischemic origin.

3. Assessment of effort tolerance and to prescribe guide lines for exercise in patients of Diabetes Mellitus.

M A T E R I A L A N D M E T H O D S

MATERIAL AND METHODS

The present study was conducted in the department of Medicine, M.L.B. Medical College, Hospital, Jhansi from June, 1990 to August, 1991. The treadmill stress ECG Room, where this study was performed, was fully equipped with Treadmill Stress test system, monitor-defibrillator and emergency drugs for management of any complication during exercise. To maintain comfortable temperature and humidity inside the room, two airconditioners of 1.5 tons each were installed with airtight doors and windows.

TREADMILL STRESS TEST SYSTEM

This system built by Eaton Medical Group, Michigan, U.S.A., included following parts :

1. Health track II Treadmill.
2. HT-7 Controller.
3. G-7000 automatic full disclosure monitor.

A. Health Track II Treadmill

Belt speed range	:	1.0 to 10.0 MPH. (1.6 to 16.1 KPM)
Grade range		0.0 to 25%
Patient weight capacity	:	375 lbs
Nominal walking surface	:	18" x 18"
Walking surface height	:	5.5"
Overall weight	:	365 lbs.
Operating temperature	:	50 to 90°F (10 to 35°C).

Operating humidity : 15-92%

Power requirement - 120 VAC 60 Ms at 20 Amp nominal

A servo control voltage stabilizer was used to maintain steady power supply.

Treadmill could be operated by either HT-7 programmable controller or Treadmill controller fixed on front hand rail or monitor which was kept along the side of treadmill. I operated treadmill with the programmable automatic G-7000 monitor using pre-recorded modified Bruce protocol on a floppy disc.

HT-7 CONTROLLER

This controller displays several read outs - speed, grade, time, distance and a message. This can be operated with two modes - manual and protocol. Beside either speed or grade, are the 'UP/DOWN' button that allow changes in the manual mode. By pressing the buttons, speed or grade can either be increased or decreased in present single step increments. By using protocol, speed and grade are automatically changed accordingly. This controller performs all operations except starting and stopping the treadmill. I used this controller only for display speed, grade, time and distance.

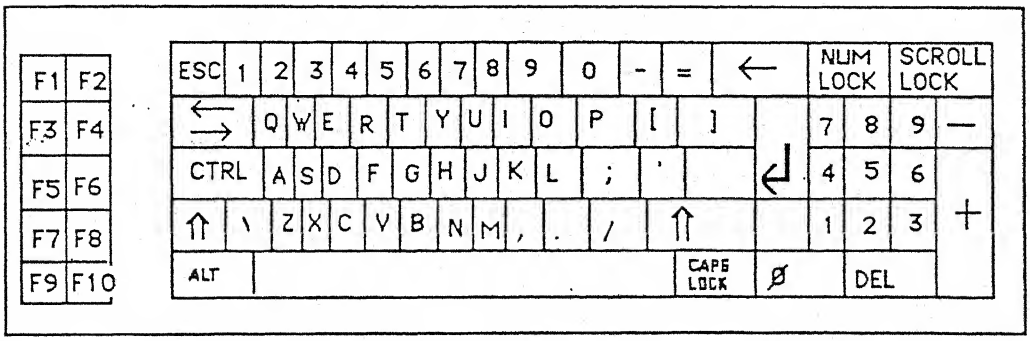
G-7000 AUTOMATIC FULL DISCLOSURE MONITOR

The G-7000 is designed to operate with the health track-II treadmill. The system operates either on manual or protocol mode. I made modified Bruce protocol

disk to operate it. There are two centres for performing functions, the keyboard and the keypad.

THE KEY BOARD

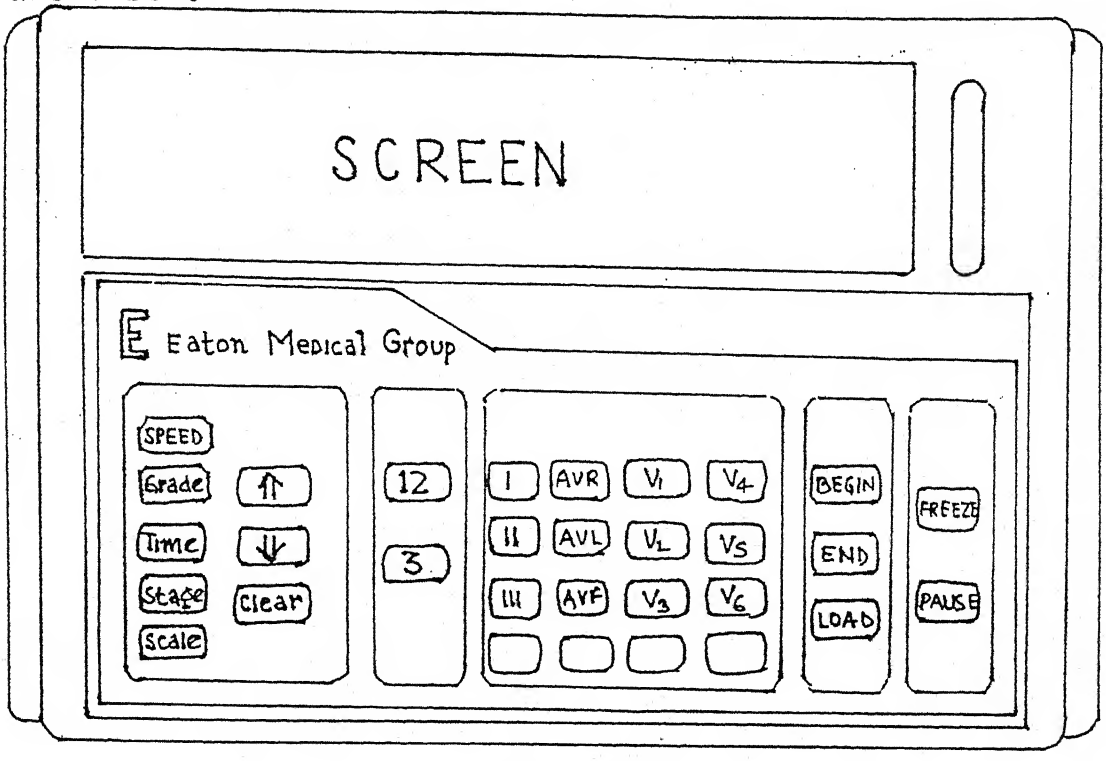
The keyboard is used to type patients' information and to move the cursor into key field positions. The return Key (←┘) is used to move the cursor forward (clockwise). The back space key (←) moves the cursor backward (Counter-clockwise). While typing information in the patients' information area, the back space key erases information.



Keyboard

THE KEY PAD

The functions are clearly labelled on each key. An audible tone indicates that a function key is properly depressed.



KEY PAD

FUNCTIONS

G-7000 system functions are initiated by using a combination of keyboard and the key pad. Active functions are accomplished by using the keypad. Informative functions are generally accomplished by using the key board.

PATIENT INFORMATION ENTRY

By using cursors, patient's data were entered in information area consisting of 3 lines, having space for 34 letters. Department of Medicine, M.L.B. Medical

College, Jhansi was entered in first line and patient's name, age, sex, symptoms, risk factors and other comments in 2nd and 3rd lines. Line IV has space for 15 letters. The 15 characters that were typed in this area are stored periodically. This area of last line was utilized to type in blood pressure during the test.

ECG TRACE DISPLAY

The monitor displays four ECG traces. Traces one, two and three display preselected leads. Leads V_5, II and VI were selected for first three traces, the bottom trace is a 2.5 second continuous rotation in 12 leads.

HEART RATE DISPLAY

The heart rate is displayed in the upper right corner of the monitor. The heart rate is updated every six seconds and is calculated from the ECG trace at the top of the monitor (trace one), I used V_5 lead for heart rate display. If R wave in V_5 was too small to give enough signal for displaying heart rate, an alternative appropriate lead was shifted to trace position to obtain heart rate display.

S-T MEASUREMENTS

The S-T measurements were monitored continuously and were updated every six seconds. They were calculated from the trace at the top of the monitor (V_5). There are three methods used to calculate the S-T measurements.

Method used in this study calculates the 'J point' by measuring a percentage of R-R interval. This is displayed on the monitor as 'PCT 12 A'. This means the 'J point' is set at 12% of the R-R interval. I measured S-T segment directly from paper tracing.

OPERATION MODE SELECTION

I used protocol mode by using modified Bruce protocol disk. Stress test is automatically controlled by touching "load protocol" on keypad. To start the test, "Pause timer" is touched after mounting the patient on the treadmill.

12 LEAD RECORDINGS

At the end of every stage 12 leads are automatically recorded. 12 lead recording can be obtained at any time by touching 12 lead on the keypad.

3 LEAD RECORDINGS

Three lead recording of the three traces on the monitor can be generated by touching '3 lead' on the keypad.

PROTOCOL USED : Modified Bruce Protocol

(Pre-recorded disc)

Stage	Speed (KPH)	Grade (%)	Duration (min.)	METS (Unit)	Total time elapsed (min.)
0	1.7	0	3	1.5	3
1	2.8	5	3	2.5	6
2	2.8	10	3	5.0	9
3	4.1	12	3	7.0	12
4	5.5	14	3	10.0	15
5	6.7	16	3	13.0	18
6	8.0	18	3	16.0	21
7	8.8	20	3	19.0	24
RE	1.7	0	5	-	-

Following equipments were available in the exercise room.

Necessary for test

1. Stethoscope.
2. Sphygmomanometer.
3. Disposable ECG electrodes.
4. Patient's bed and pillow.
5. Loose gown and pyzama of different size.
6. Light weight shoes of different size.
7. Adhesive tape, shaving rajor and blade, '0' number sand paper, cotton, guage, sprit, savlon, tincture Benzoin.

Equipments necessary for dealing any Emergency

1. D.C. defibrillator(both rechargeable battery-cum-mains operation)
2. External demand pacemaker and pacemaker electrodes.
3. Ventimask, O_2 cylinder.
4. Cut down tray with disposable syringe and needles I.V. sets, I.V. stand, Intracardiac needles.

Drugs

I/V fluids 5% dextrose
Inj. Aminophyllin
Inj. Lanoxin
Inj. Lasix
Inj. Lignocaine
Inj. Mexiletine
Inj. Pethidine
Inj. Nor-adrenaline
Inj. Phenargan
Inj. Dopamine
Inj. Urokinase - 2 vials were kept always in ICCU(2,50,000 and 5,00,000 Units).
Inj. Amioderone.
Inj. Isoptin
Inj. Epsolin
Inj. Dexona shock pack
Inj. Kesol
Inj. Sodabicarb
Inj. $CaCl_2$
Inj. Atropine
Inj. Adrenaline
Inj. Alupent
Inj. Mephentine
Inj. Amrinone.

SOURCE OF PATIENTS

The subjects for treadmill testing were selected from the patients who attended O.P.D., admitted in wards and referrals from other hospitals. Detailed history, clinical examination and investigations were completed under headings given in appendix prior to treadmill test.

INSTRUCTIONS TO THE PATIENTS

Following instructions were given to the patients.

1. The patient was told to stop consumption of drugs (if he was doing so) affecting the cardiovascular system like digitalis, Beta blockers, Ca channel blockers, Nitrates, tricyclic antidepressants, anti-arrhythmic etc. so as to avoid false positive and false negative results at least for 3 days. Hypertensives who had been on beta blockers/Ca channel blockers for their blood pressure control were asked to discontinue the same and if they needed antihypertensive drugs, they were preferably kept on drugs which were supposed not to interfere with Treadmill test like methyldopa or ACE inhibitors . On doing so if the patients experienced any symptoms, they were asked to report back or to consult the treating doctor.
2. Patient was asked to stop smoking and consumption of alcohol at least 24 hours prior to appearing for test.
3. Patient was asked to have only a light meal 2-3 hours before appearing for the test.
4. Patient was instructed to report in the exercise room at least 1 hour prior to commencement of the test so as to remain well accustomed to the surroundings of treadmill room.
5. He/She was encouraged to be fully relaxed.
6. Test was never performed if patient was unaccompanied by a major friend or family member.

PREPARATION OF THE PATIENT

To begin with, the patient was fully explained about the procedure of the test along with the associated risk (mortality and morbidity 1 in 10,000). An informed consent (on a typed consent form) was obtained, prior to the test signed by the patient or his/her attendant and witnessed by the physician.

Loose fitting gown and pyzama and light weight shoes of proper size were given to the patient to wear. The quality of the recorded ECG signal is the single most important technical aspect of exercise electrocardiography. The proper choice of electrodes and skin preparation at the site of electrode placement insure the greatest likelihood of obtaining high quality ECG records with submaximal and maximal exercise testing. In at least 10 per cent of patients with exercise-induced ischemia the S-T segment abnormalities will appear only during exercise and excessive noice, motion artifact, or baseline drift may obscure the diagnostic S-T segment changes. Potentially dangerous exercise-induced arrhythmias may also be missed.

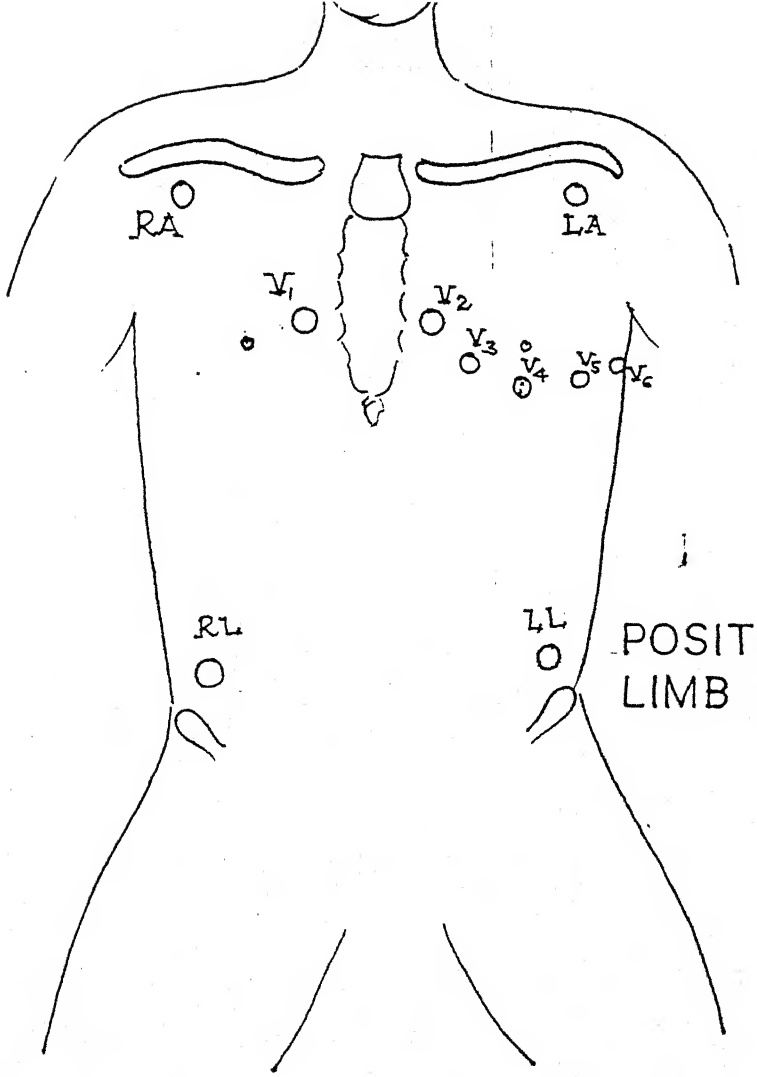
Adequate skin preparation consists of first cleansing the sites of electrode application with ethyl alcohol, followed by removal of the superficial epidermal layer with a dental burr mounted on a high speed drill or by light abrasion with fine-grain sandpaper. Too vigorous debridement should be avoided to prevent edema formation and an increase in electrical resistance at the electrode-

skin interface. Once the superficial epidermal layer is loosened, it should be washed away by light cleansing with acetone.

The optimal electrode is one of the silver-silver chloride composition. The electrode should be one centimeter in diameter or less and encased in a lightweight plastic well which is two or three millimeters deep. This design avoids electrode contact with the skin and reduces baseline drift.

In female subjects, the exercise ECG should be carried out with the patient wearing an undergarment to support the breasts. This will prevent the motion artifact caused by movement of the chest electrode by the breasts during exercise.

Site : One each on right and left infraclavicular region, one each on right and left hypochoandriac region and six on precordial region (V_1 to V_6 position) then the connectors were snapped to the electrodes and tied with the belt. Patient was instructed to have a rest comfortably in the supine position for at least 10 min. before the actual exercise was performed.



POSITION OF DIFFERENT LIMB AND CHEST LEADS

- By snapping on the buttons of electrodes it was ensured that there is no shift of baseline/significant disturbance in the trace on the monitor. If any of these defects were present, the same was removed and was applied again after repeat skin preparation.
- Blood pressure was measured with a cuff sphygmomanometer and 12 lead ECG was recorded in supine and erect position after hyperventilation for 3 minutes before starting exercise.
- Instruction was given to the patient to mount on the treadmill belt by placing both feet on the same side of the platform, then using a skating motion with

one foot only on the belt, with weight on the other foot, then step on the belt with the other foot. The patient was instructed to walk as normally and upright as possible.

Following other instructions were also given to the patients :

1. Do not grip the hand rail hardly and use it for balance only.
2. Walk with a normal gait.
3. Walk with as long pace as possible before running.
4. Remain toward the front of the walking surface.
5. Do not look at his/her feet, keep his/her head up.

Each patient performed a treadmill exercise test by the modified Bruce protocol.

The electrocardiogram was monitored continuously by 3 lead system (V_5, II, V_1) and 12 leads ECG was recorded, at each stage, at the onset of S-T segment depression, at peak exercise and at regular interval after exercise (recovery period) with the patient supine until symptoms and/or S-T change was resolved or for a minimum of 5 minutes.

The patients were instructed to exercise until limited by symptoms of fatigue or increasing chest pain.

The criteria of termination of treadmill test were as follows :

1. Patient's request (inspite of motivation).

2. Significant symptoms or signs : severe chest pain, ataxia, vertigo, confusion, pallor, cyanosis.
3. Reduction of blood pressure and/or heart rate during increasing work load.
4. Serious arrhythmias : grouped (3 or more) VPC's ventricular tachycardia, ventricular fibrillation.

- Acute myocardial infarction.
- Malfunctioning equipment (Treadmill monitor).
- Marked hypertension (systolic blood pressure above 220 mm Hg or diastolic pressure above 120 mm Hg).
- Marked (2 mm or more) horizontal, downsloping or upsloping S-T segment depression.
- Achievement of 85% to 90% of target heart rate.

Target heart rate for the exercise ECG test.

Age	85-90% of maximal heart rate	Maximal heart rate
20 - 29	175 - 100	190
30 - 39	170 - 175	182
40 - 49	165 - 170	179
50 - 59	160 - 165	171
60 - 69	155 - 160	164
70 and above	150 - 155	160

In each patient the following exercise parameters were recorded for interpretation.

- Resting ECG.
- Total grade achieved.

- Total duration of exercise.
- The presence or absence of typical ischemic chest pain.
- The time of onset of S-T segment depression(71 mm).
- The heart rate at the onset of S-T segment depression.
- The maximum depth and its persistence after exercise.
- The maximal heart rate achieved.
- The blood pressure at peak exercise.
- The change in B.P. from rest to this point.
- The product of heart rate and systolic blood pressure at peak exercise.
- The R wave amplitude.
- Cardiac arrhythmias and its nature.
- Total duration of recovery, duration of persistence of S-T segment depression, chest pain, ventricular, arrhythmias during recovery.
- Signs of left ventricular dysfunction.
- Functional aerobic impairment.
- Total METS at peak exercise.
- Maximum VO_2.

According to onset of S-T depression, its depth, and persistence during recovery period, Treadmill test were considered to be strongly, moderately or mildly positive for myocardial ischemia.

Following TMT responses were considered to have predictive import for angiographically documented

severe, multivessel and/or left main coronary artery disease (strongly positive test).

1. S-T segment depression more than 2 mm.
2. Early onset (first 3 minutes) of ischemia S-T depression (7 1 mm).
3. Prolonged duration (7 8 minutes) in the post exercise recovery period of ischemic S-T segment depression.

O B S E R V A T I O N S

OBSERVATIONS

The present study entitled "Evaluation of cardiovascular status of diabetic patients by stress streadmill ECG test" was performed in the department of Medicine, M.L.B. Medical College, Jhansi, (UP) INDIA.

Sixty eight subjects were selected for this study who underwent treadmill testing. Four patients could not achieve age predicted target heart rate and the test was terminated prematurely in these subjects because of exhaustion. In sixty four patients multivariate analysis of exercise electrocardiography and non electrocardiographic changes was done and following results were observed.

The distribution of subjects in different age groups is shown in figure 1. Eight (12.5%) patients were under forty years of age and included four males and four females. Twenty six (40.62%) patients belonged to fifth decade and included six females and twenty males. In sixth decade there were twenty (31.25%) patients, all males. Ten (15.64%) were over sixty years of age and this group included eight males and two females. The youngest patient was forty three years old and the oldest was of sixty five years.

In this study, out of sixty four patients, fifty two (81.25%) were male and twelve (18.75%) were female patients. Thus male to female ratio was 4.3 : 1(Figure 2).

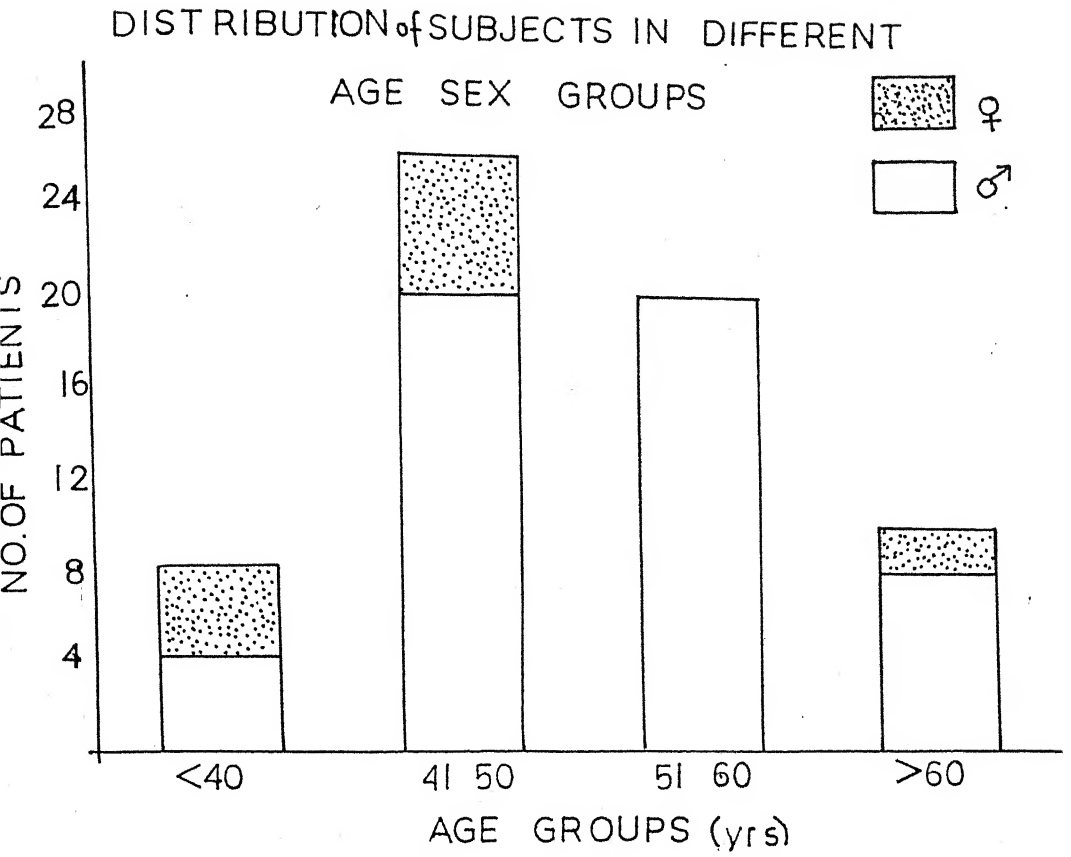
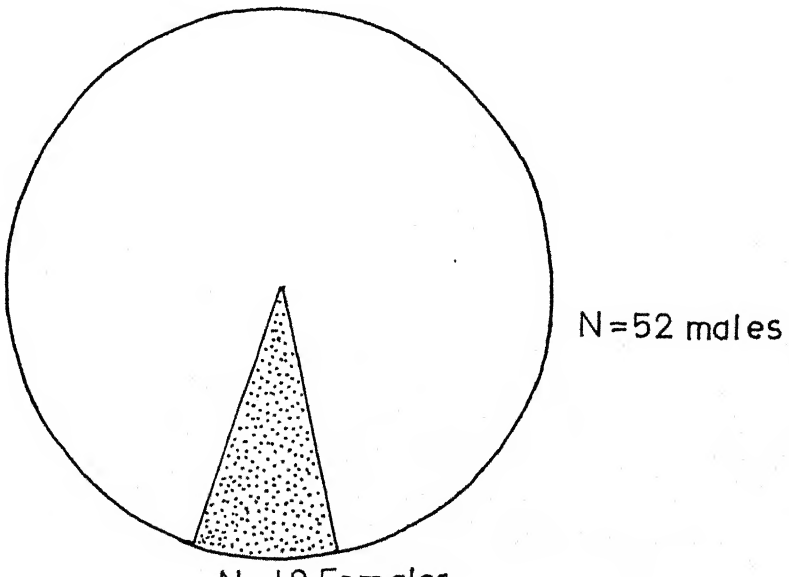


FIGURE ONE.



Pie diagram showing MALE: FEMALE ratio

FIGURE TWO.

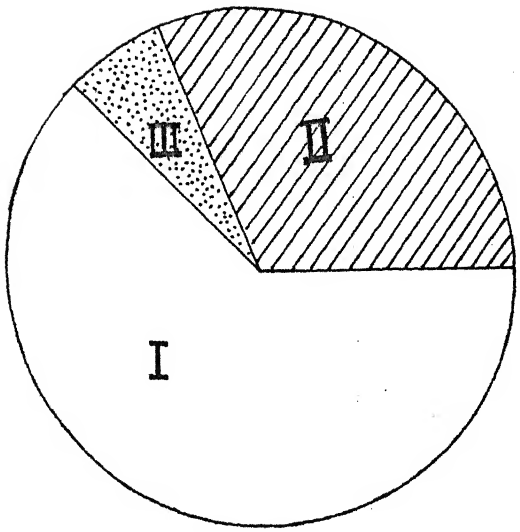


FIGURE THREE. PIE DIAGRAM TO SHOW DISTRIBUTION OF PATIENTS IN DIFFERENT NYHA CLASSES

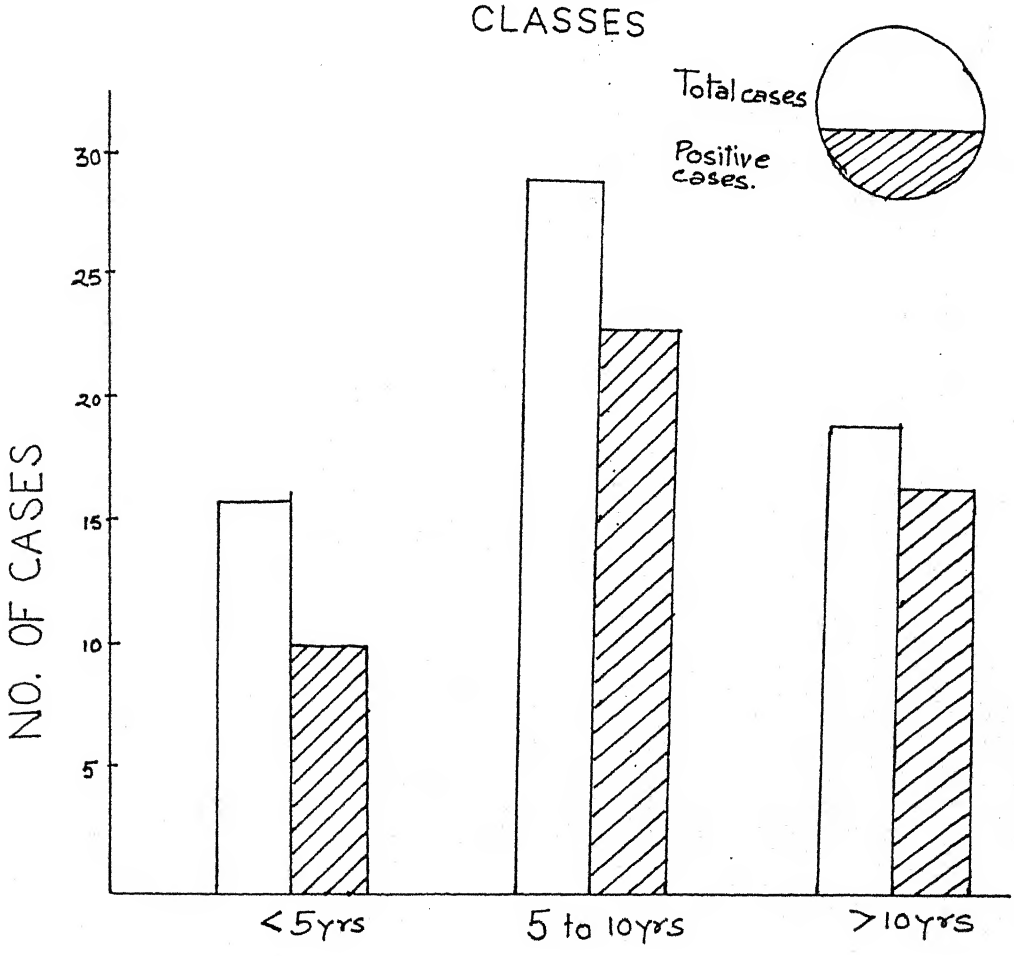
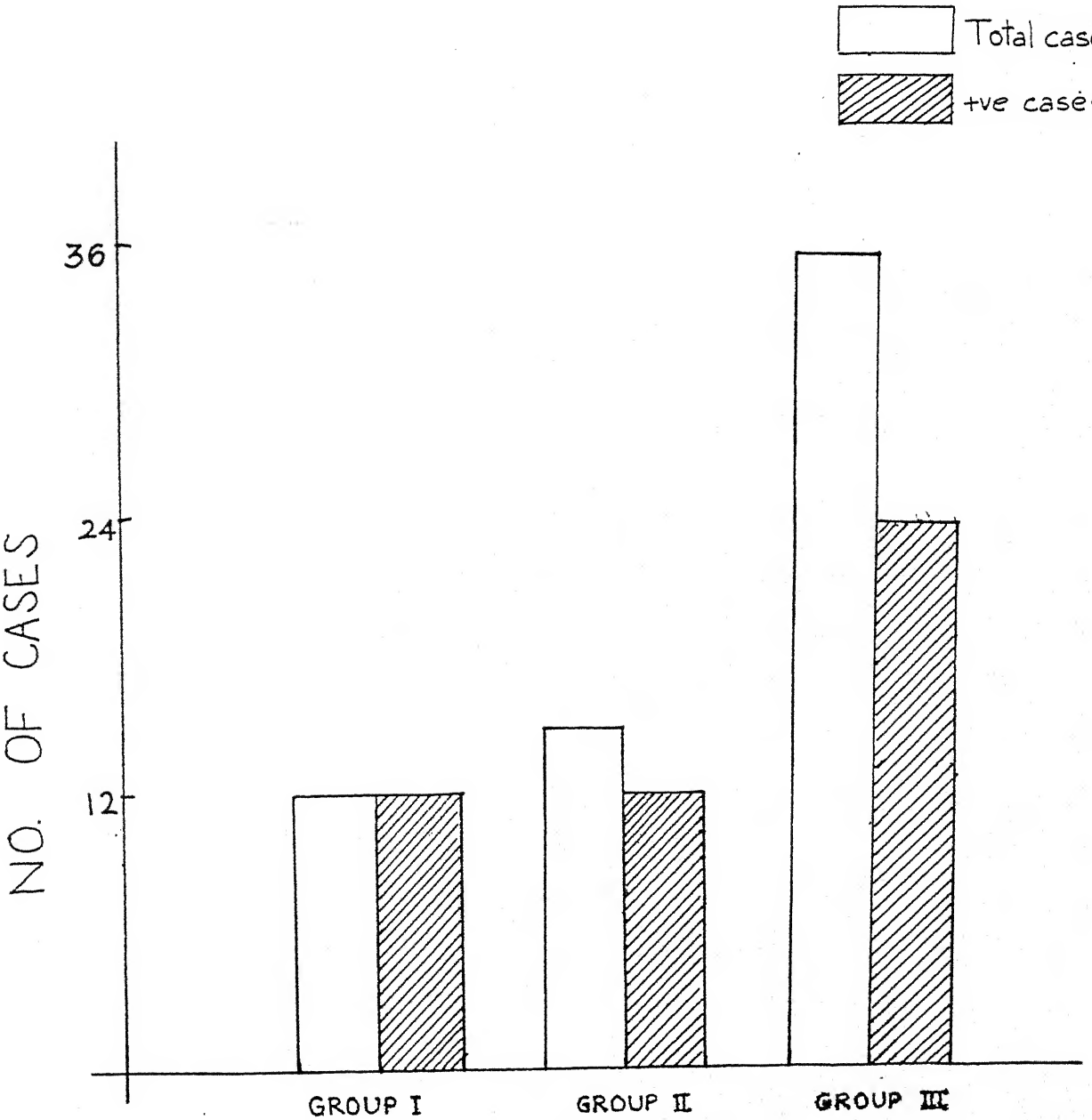


FIGURE FOUR. RELATIONSHIP OF DURATION OF DIABETES WITH POSITIVITY OF T.M.T.



DISTRIBUTION OF T.M.T. POSITIVITY IN DIFFERENT STUDY GROUPS

FIGURE FIVE.

The overall sex distribution in different age groups is shown in table 1.

TABLE 1

Distribution of subjects according to their age and sex.

Age groups (years)	Male	Female	Total	Percentage
≤ 40	4	4	8	12.50
41 - 50	20	6	26	40.62
51 - 60	20	-	20	31.25
≥60	8	2	10	15.64
TOTAL	52	12	64	100.00

TABLE 2

Distribution of subjects in different NYHA classes.

NYHA class*	No. of cases	Percentage
I	42	65.62
II	19	29.69
III	3	4.69
TOTAL	64	100.00

* There was no case from class IV.

Out of sixty four cases, forty two (65.62%) belonged to NYHA class I, nineteen (29.69%) to class II and three (4.69%) to class III. There was no patient in class IV of NYHA(Table 2).

Among all sixty four patients, forty nine patients had normal resting twelve lead electrocardiogram.

Eleven patients had non specific ST-T changes and one patient had 1 mm S-T depression which persisted throughout the exercise period. Two patients had ventricular ectopics in their ECGs.

Out of sixty four patients, forty one had one or more coronary risk factors viz. systemic hypertension, in twenty four (37.50%), smoking in nineteen (29.68%), obesity in eight (12.5%), family history of premature CAD in nine (14.06%) and hyperlipidemia in eighteen (28.13%). Twenty three patients were without any coronary risk factors. The incidence of coronary artery disease was found higher in those who had one or more coronary risk factors as compared to the patients without these (Table 3).

TABLE 3

Distribution of subjects in relation with coronary risk factors.

Risk factors	No.of cases	Percentage
Systemic hypertension	24	37.50
Smoking	19	29.68
Family history of premature CAD	9	14.06
Obesity	8	12.50
Hyperlipidemia	18	28.13

Note : In some subjects more than one risk factor was present while in others, there was no risk factor.

TABLE 4

Relationship of duration of diabetes with positivity of treadmill test.

Duration of diabetes (years)	Total No.of cases	Treadmill positive cases				
		1 mm	1.5 mm	2 mm	Total	Percentage
< 5	16	4	2	4	10	62.50
5 - 10	29	3	6	14	23	74.31
>10	19	5	4	8	17	89.47

All sixty four patients who participated in the test were classified in three groups according to the duration of diabetes. Group one included the patients who were diabetic for less than five years. This group included sixteen patients and ten (62.50%) were found to have ischemic heart disease. Group two included those diabetics who had it upto 10 years and comprised of 29 patients including 23(74.31%) TMT positive cases. Those patients who had diabetes for more than 10 years were included in group three and comprised of nineteen patients. Out of which seventeen (89.47%) were positive for TMT.

TABLE 5

Distribution of subjects in different resting heart rate groups.

Resting HR/minute	No.of cases	Percentage
≤ 70	14	21.88
71 - 80	12	18.75
81 - 90	14	21.88
91 - 100	12	18.75
≥ 100	12	18.75

Table 5 shows the distribution of subjects in various ranges of resting heart rate. It was found that patients who had higher resting heart rates included majority of females and had an element of anxiety.

TABLE 6

Distribution of subjects in different resting blood pressure groups.

Resting systolic B.P. (mm Hg)	No.of cases	Percentage
≤120	2	3.13
121 - 130	12	18.75
131 - 140	14	21.87
141 - 150	24	37.50
≥ 150	12	18.75

Table 6 shows the distribution of resting blood pressure. Only two patients had resting systolic B.P.

less than 120 mm Hg, while twelve had higher than 150 mm Hg.

All sixty four patients were classified in three study groups according to the nature of chest pain. Group I comprised of those subjects having history of typical angina. Group II comprised of those subjects who had atypical chest pain probably of ischemic origin. Group III included patients who had atypical chest pain probably of non ischemic origin. Presence or absence of risk factors, favourable age, sex etc were considered as criteria for the probability of pain to be ischemic or non ischemic origin.

Group I included twelve (18.75%), group II sixteen (25%) and group III thirty six (56.25%) patients as shown in table 7.

TABLE 7

Showing the distribution of subjects in three study groups.

Study groups	Male No. (%)	Female No. (%)	Total No. (%)
Typical chest pain suggestive of Angina pectoris	8(12.50)	4(6.25)	12(18.75)
Atypical chest pain probably of I.O.	16(25.00)	-	16(25.00)
Atypical chest pain probably N.I.O.	30(46.87)	6(9.37)	36(56.25)
TOTAL	54(84.37)	10(15.62)	64(100.0)

Out of sixty four patients, fifty (78.13%) had positive T.M.T. test and in fourteen (21.87%) T.M.T. test was negative. Among those who had positive test, twenty six (40.63%) had S-T segment depression of two mm or more. Twelve (18.75%) had 1.5 mm S-T segment depression and 1 mm S-T depression was observed in twelve (18.75%) patients only.

TABLE 8

Distribution of S-T segment shift among TMT positive subjects.

S-T change	No.of cases	Percentage
$\geq$ 2 mm S-T depression	26	40.63
1.5 mm S-T depression	12	18.75
1 mm S-T depression	12	18.75

Out of fifty positive cases, two patients were below the age of forty years, twenty four belonged to fifth decade of life, eighteen were in their sixth decade and six patients were beyond the age of sixty year.

Out of fifty two male patients forty two had positive test (80.77%) and out of twelve females who were subjected to treadmill test, eight (66.67%) had positive test(Table 9).

TABLE 9

Distribution of TMT positive cases in different age/sex groups.

Age groups (years)	Total cases	Male	Female	T.M.T. Positive cases		
				Male	Female	Total
≤ 40	6	4	2	2	-	2
41 - 50	26	20	6	18	6	24
51 - 60	22	20	2	18	-	18
≥ 60	10	8	2	4	2	6
TOTAL	64	52	12	42	8	50

When the magnitude of S-T segment depression was observed in group I (typical chest pain), twelve had S-T segment shift which was two mm or more in 8 patients, 1.5 mm in two and 1 mm in two patients.

In group II (atypical chest pain probably of ischemic origin) fourteen had S-T segment shift which was two mm or more in twelve and one mm in two patients.

In group III (atypical chest pain probably of non ischemic origin) twenty six had S-T segment shift which was two mm or more in six patients, 1.5 mm in ten and remaining ten also had a shift of 1 mm during exercise period (Table 10).

TABLE 10

Distribution of TMT positivity in different study groups.

Study groups	No.of cases	Magnitude of S-T depression ≥ 2	1.5	1	Total	%
Typical chest pain suggestive of Angina pectoris	12	8	2	2	12	100.0
Atypical chest pain probably of I.O.	16	12	-	2	14	87.50
Atypical chest pain probably of N.I.O.	36	6	10	8	24	72.20
Total	64	26	12	12	50	86.57

TABLE 11

Distribution of patients in relation to chest pain and ST-T changes in various study groups.

Study groups	Patients having chest pain during exercise		Patients having no chest pain during exercise		TOTAL
	With ST-T changes	Without ST-T changes	With ST-T changes	Without ST-T changes	
Typical chest pain suggestive of angina pectoris	11	-	1	-	12
Atypical chest pain probably of I.O.	8	-	6	2	16
Atypical chest pain probably of N.I.O.	7	2	17	10	36
TOTAL	26(14.6%)	2(3.1%)	24(37.5%)	12(18.8%)	64

Out of sixty four patients, twenty eight(41.8%) had chest pain during exercise. Among these twenty eight

patients, twenty six (40.6%) had S-T segment depression while in two there was no S-T depression, however, they achieved their age predicted heart rate. In group III there was seventeen patients who had S-T segment change without chest pain during exercise (Table 11).

TABLE 12

Distribution of other exercise variables among various subjects.

Variables	No.of cases	Perce-ntage	With S-T Depression	Without S-T Depression
Angina	28	43.8	26	2
Abnormal B.P. response	12	18.7	10	2
VPC's	3	4.7	3	-
R wave amplitude	7	10.9	7	-
Angina with VPC's	3	4.7	3	-
Angina with abnormal blood pressure	10	15.6	10	-

Out of sixty four patients, twenty eight had angina. Ten (15.6%) had angina with abnormal B.P. response and all ten had S-T segment depression. Three patients had angina and premature ventricular contractions. Twelve (18.7%) had abnormal B.P. response and three (4.7%) had premature ventricular contractions while abnormal R wave response was observed in seven (10.9%) cases.

TABLE 13

Relation of risk factors with positivity of TMT.

No.of risk factors	Total cases	Magnitude of S-T depression			Total +ve cases	Percentage
		≥ 2 mm	1.5 mm	1 mm		
0	7	3	-	1	4	57.1
1	39	10	12	7	29	74.3
2	15	10	-	4	14	93.3
3	3	3	-	-	3	100.0
TOTAL	64	26	12	12	50	-

Out of sixty four patients, seven had no risk factor but four (57.1) patients had positive treadmill test, thirty nine patients had only one risk factor and of these twenty nine (74.3%) had positive test, in fifteen patients two risk factors were present and of these fourteen (93.3%) had S-T segment depression, in three patients three risk factors were present in each and all turned out to be treadmill positive case. It was very clear from this study that chances of positivity of treadmill increase with increase in number of risk factors.

TABLE 14

Relationship of positivity of treadmill with NYHA class.

NYHA class	Total No.of cases	T.M.T. Positivity			
		1 mm	1.5 mm	$\bar{7}$ 2 mm	Total
I	42	6(21.42%)	8(28.58%)	14(50.0%)	28(66.67%)
II	19	2(11.76%)	4(23.52%)	11(64.72%)	17(89.47%)
III	3	2(66.67%)	-	1(33.33%)	3(100.0%)
IV	-	-	-	-	-

Out of forty two patients, who belonged to NYHA class I, twenty eight (66.67%) developed S-T segment depression and it was 1 mm in six cases, 1.5 mm in eight and 2 mm or more in fourteen cases. Nineteen cases belonged to class II, having seventeen (89.47%) TMT positive cases. In these patients 1 mm S-T depression was in two cases, 1.5 mm in 4 cases and 2 mm or more in eleven cases. Only three patients were in class III and all the three developed S-T depression in early phase of exercise. Out of them two had 1 mm and one had more than 2 mm S-T depression. There was no patient in class IV who performed exercise.

The stage in which S-T depression of 1 mm or more was observed was specifically noted. In sixteen (32%) it started in stage I, in eighteen (36%) in stage II, in twelve (24%) in stage III while four (8%) reached stage IV when S-T depression was noticed (Table 15).

TABLE 15

Distribution of onset of S-T depression in different stages.

Stage	Onset of S-T depression No.	Percentage
I	16	32.00
II	18	36.00
III	12	24.00
IV	4	8.00
TOTAL	50	100.00

TABLE 16

Showing relation of positivity of treadmill with different stages achieved.

Stage	Duration (min.)	No.of cases	TMT Positive cases	TMT Negative cases
I	$\angle$ 3	6	6	-
II	3 - 6	15	14	1
III	6 - 9	27	20	7
IV	9 - 12	16	10	6
TOTAL		64	50	14

Out of sixty four patients, six could perform exercise upto stage I only and all had significant S-T segment depression. Fifteen patients could exercise upto stage II. Out of whom fourteen had significant S-T segment depression. There were twenty seven patients who performed exercise upto stage III and twenty of them

showed S-T shift while seven achieved the age predicted heart rate without S-T depression. Sixteen patients could enter stage IV and ten of these turned out to be TMT positive and six negative.

TABLE 17

Distribution of S-T depression in different double product groups.

Double product range	No.of casès	No.of cases C S-T depre-ssion	S-T depression cases			Total +ve	Perce-ntage
			1	1.5	≥ 2		
∠ 20000	8	-	2	2	4	8	100.00
Upto 25000	16	-	2	2	12	16	100.00
Upto 30000	18	6	4	2	6	12	66.67
Upto 35000	20	6	4	6	4	14	70.00
Upto 40000	2	2	-	-	-	-	00.00
TOTAL	64	14	12	12	26	50	84.17

Out of sixty four patients, eight achieved double product upto 20,000 and all the eight turned out to be TMT positive, sixteen cases achieved double product upto 25,000 and all were TMT positive, eighteen cases achieved double product upto 30,000 out of these, twelve (66.67%) were positive, twenty patients achieved double product upto 35,000 including fourteen (70%) TMT positive cases and two cases achieved double product upto 40,000 both these cases were TMT negative.

TABLE 18

Relation of positivity of treadmill with total METS achieved.

METS achieved	No.of TMT +ve cases	No. of TMT -ve cases	Total	Percentage
2 - 3	4	-	4	100
4 - 6	18	2	20	90
6 - 10	24	8	32	75
710	4	4	8	50
TOTAL	50	14	64	—

Out of sixty four patients four patients performed exercise upto 2-3 METS (Class III) and all the four patients were treadmill positive, twenty patients performed exercise upto 4-6 METS (Class II) and eighteen cases were treadmill positive and two were negative, thirty two patients performed exercise upto 6-10 METS (Class I), of these twenty four were positive and eight were negative, eight patients performed exercise beyond ten METS and 50% of these patients were treadmill positive.

Sixty eight diabetic patients performed the stress treadmill ECG test, the procedure was fully explained to the patients and all possible efforts were made to adjust the patients with the surroundings of treadmill room. In spite of all efforts four patients could not perform exercise to significant level so that their treadmill report could'nt be interpreted to conclusion. They were asked to do fast walking exercise and report again for a repeat TMT. These cases were not included in the study. In eight (12.50%) patients sudden rise of heart rate was observed when they just started the exercise in stage I and they took some time to become normal, in such patients the B.P. was also higher in stage I as compared to stage II B.P..

In this study thirty six (56.25%) such patients had undergone treadmill testing and twenty six (72.2%) patients of these were found to have positive treadmill test, out of these 26 patients only nine experienced chest pain and seventeen developed S-T depression without chest pain during exercise. Therefore, silent ischemia was found common in these patients.

During the entire length of study none of the patients developed any major complication.

D I S C U S S I O N

DISCUSSION

Diabetes mellitus is known for centuries and it is a world wide disease. It involves many systems of body cardiovascular involvement having its own significance. Early onset of atheroma, cerebrovascular disorders specially thrombosis, occlusion of major vessels lead to ischemia and even gangrene of limbs.

Ischemic heart disease has become the most important cause of premature death and disability. The disease may result in sudden death or it may manifest itself as an acute and often fatal attack of myocardial infarction or as angina pectoris. It remains the leading cause of death inspite of all efforts made by scientists in the field of investigations and treatment. The disease has been studied in different parts of the world and the new technologies are coming day by day but still we have to know a lot about them.

There is sufficient evidence to conclude that the incidence of diabetes mellitus is increasing. In India 2.1% of urban population and 1.5% of the rural population suffer from the disease. The incidence increases with age. Male to female ratio is 2.6 : 1.8. In western countries diabetes mellitus is more common in females.

Coronary artery disease has been reported to be on the increase in India. Various studies indicate that

incidence of CAD ranges from 6 to 20% of all heart patients. The pattern of coronary artery disease in India has been reported by Sinha (1978). The prevalence of coronary artery disease is much more common in males as compared to females. The ratio being 4 : 1, but it is not true at extreme of age when the coronary incidence becomes more or less same. In India CAD appears a decade earlier in life as compared to the age incidence in developed countries. Association of coronary risk factors play very important role in development and severity of coronary artery disease. Those patients who have multiple coronary risk factors are very much prone to develop coronary artery disease.

In diabetics, the incidence of coronary artery disease increases manifold . The difference in premenopausal diabetics is even more noteworthy. The present study was conducted in the department of Medicine, M.L.B. Medical College, Hospital, Jhansi from June' 1990 to Aug , 1991. Sixty eight patients were selected for this study but four of them could not perform enough exercise to achieve age predicted heart rate so they were not considered subsequently and thus study comprised of sixty four patients. Out of these maximum number of patients (40.62%) were from 41 to 50 years of age while there were only eight (12.5%) patients below the age of forty years. When patients were classified in different NYHA classes,

majority of patients were from class I while there were only three (4.69%) patients from class III, all three patients of this class were found to have positive treadmill test while the incidence of positivity was less in patients who belonged to NYHA class I. It was also observed that capacity to do exercise also decreases as the NYHA class is increased. In this study those who belonged to class III had their treadmill test positive in very early stages of modified Bruce protocol. The exercise duration was much higher in patients of class I as compared to II and III NYHA classes.

Majority of patients belonged to middle class and most of them were from urban area, only six patients were from rural area. Male to female ratio in this study was 4.3 : 1. Most of the male subjects were from service class while most of the females were house wives. Most of the patients were active but few patients in this study were sedentary, it was specially so with the females.

In the present study risk factors were present in good number of cases (89%). Only seven patients were without any coronary risk factors and incidence of positivity was 43% higher in those who had more than two risk factors. There was poor correlation of the magnitude of S-T depression with the number of risk factors.

Hypertension was the commonest coronary risk factor in this study, smoking being the next culprit.

Growing emphasis on early diagnosis and prevention of coronary artery disease has made the exercise laboratory the integral part of any cardiac set up. Although evaluation of cardiovascular function in the resting state provides some useful information but examination of the circulatory response to stress is much more sensitive and informative (Epstein et al, 1967). Treadmill is one of the most important and valuable non-invasive diagnostic tests in the clinical evaluation of patients with suspected or known coronary artery disease (Chung, 1973).

In the present study the following criteria were utilized to call the test positive.

1. S-T segment depression of one mm or more if it is horizontal or down sloping.
2. When S-T segment depression was upsloping, the test was considered positive only when S-T segment was more than 1 mm dipressed after 80 m sec from j point otherwise it was labelled negative.

In present study, it was not possible to get sensitivity and specificity of the treadmill test since we had no gold standard test like coronary angiography. In this hospital facility for coronary angiography does not exist. All the patients from NYHA class III were found to have strongly positive treadmill test. The criteria for strongly positive treadmill test were early

onset (first three minutes of Bruce Protocol), more than two mm S-T depression (horizontal or downsloping) and slow recovery (persistence of S-T segment depression for more than eight minutes in post exercise period). The concept that marked S-T segment depression is associated with a more severe degree of coronary artery narrowing than minimal changes had been demonstrated by many investigators. Four patients who had strongly positive treadmill test in our exercise laboratory had gone for selective coronary angiography elsewhere. All of them were found having three vessel and/or left main coronary artery involvement. All angiographically documented cases had more than two mm S-T segment depression, three of them had this depression during stage I of modified Bruce protocol while one had S-T depression in stage II. Their double product was less than 30,000. Those patients in whom two mm or greater ischemic S-T depression occurs had 57% incidence of three vessel disease and 85% two vessel disease.

One of these four patients who had strongly positive treadmill test and detected on subsequent coronary angiography, was advised urgent coronary Bypass surgery, somehow he did'nt have the surgery and sustained acute inferior wall myocardial infarction after three weeks of treadmill test.

Patients with classical history of angina will be found to have coronary disease 90% of the times while

approximately 50% of patients with atypical chest pain will be found to have coronary artery disease. With an ischemic exercise response probability increases to 98% in typical angina and 87% in atypical chest pain while negative test reduces this probability to 75% and 25% in typical and atypical chest pain respectively. Patients with non ischemic pain have pretest probability of 10% while positive test increase this to 44% and negative test decreases it to 4% (Diamond, 1979).

In this study when diabetics were classified in three groups on the basis of nature of their chest pain, Group I included twelve patients and all were positive for ischemic exercise response indicating 100% incidence. When these results were compared with similar study conducted in our department one year ago in non diabetics (Jain, 1991), the probability of ischemic exercise response in this group was 83.3%. Group II included sixteen patients and out of these, fourteen were positive indicating 87.5% incidence of ischemic exercise response as compared to 41% in previously conducted study over non-diabetics. Group III, where the chest pain was considered probably of non ischemic origin, included thirty six patients and among them, exercise response was positive in 72.2%. In the above mentioned work in this department such non-diabetic patients numbering seven had negative TMT in all.

In this study out of sixty four patients 28% had chest pain during exercise as compared to 31% in previously conducted study in non-diabetics when positivity of treadmill testing is compared between present study and non-diabetics of previous study, it is 50.8% and 78.1% respectively.

In this study, twelve subjects had typical angina, sixteen had atypical chest pain and thirty six had chest pain of probably non ischemic origin, although 72.2% subjects having chest pain of probably non-ischemic origin were found to have positive test but only seven (23%) experienced chest pain and in remaining presumably myocardial ischemia was silent.

When adequate stress fails to reveal S-T segment displacement, it is unlikely that clinical coronary event will be manifested over the ensuing few years. Ellestad and Wan (1975) found that a negative stress test predicted a six fold decrease in the likelihood of developing a coronary event over the ensuing eight years compared with an ischemic S-T response.

Each level of work on the treadmill required a specific oxygen consumption per kilogram of body weight i.e. a specific multiple of resting oxygen consumption (e.g. 2 METS, 3 METS). Therefore, if it is known what number of METS are required for each stage of a particular protocol, the total METS achieved can be used as an indicator of work capacity. The following shows the relation-

ship between the New York Heart Association classes and METS.

1. Cardiac patients are able to perform exercise work load as follows :

Functional class I	-	6-10 METS
Functional class II	-	4 -6 METS
Functional class III	-	2-3 METS
Functional class IV	-	1 METS

2. Healthy subject is able to perform exercise work loads as follows :

Healthy sedentary individuals - Beyond 10-11 METS

Physically active individuals - Beyond 16 METS.

In this study out of sixty four patients, four achieved 2-3 METS (Functional class III), eighteen subjects achieved 4-6 METS (Functional class II), twenty four subjects achieved 6-10 METS(Functional class I) and four patients achieved beyond ten METS (Healthy sedentary individuals). None of the subject achieved beyond 16 METS. There is a direct correlation of severity of TMT positivity with individuals' functional class.

Class II and III patients had more positive TMT as compared to class I patients. Out of four subjects of class II all had positive TMT, in class II eighteen patients had positive TMT out of twenty patients while there were thirty two patients from class I and twenty four had positive TMT. All four subjects who achieved

beyond 10 METS were TMT negative.

The conclusion of the above data is as follows:

- There is a direct correlation of severity of CAD with functional capacity of patients i.e. more performance of exercise, less will be the chance of severe coronary artery disease.
- The individuals of this region are not well accustomed to such exercise and they are able to perform less exercise as compared to western countries(eight out of fourteen (57%) cases with negative TMT could not exercise beyond stage III, while average westerner can exercise upto stage IV).
- They achieved age predicted sub-maximal heart rate in early stages of exercise indicating poor cardiovascular conditioning.

Out of fourteen negative cases, one achieved age predictive heart rate in state II, seven did so in stage III and remaining six achieved this rate in stage IV. No patient could exercise beyond stage V.

Double product(product of heart rate and systolic blood pressure at peak of exercise) is considered to be a practical index of myocardial oxygen requirement. In this study there is ample evidence to correlate the double product with severity of coronary artery disease in the form of treadmill test positivity. Eight patients achieved double product less than 20,000 and all were

found TMT positive, it was similar in all sixteen patients also who achieved double product upto 25,000. Double product beyond 40,000 was achieved by two patients and both turned out to be TMT negative. Similar results were obtained in previously conducted study among non-diabetics (Jain, 1991). However, eight patients achieved double product beyond 40,000. On the basis of these results it is clear that increasing coronary artery obstruction, leads to reduced supply of oxygen to the myocardium, in response to increased demands, this leads to less increment of systolic blood pressure and heart rate, so S-T changes become apparent at low double product (assuming resting heart rate and systolic blood pressure in normal range).

Cole and Ellestad (1978) assessed the significance of chest pain during treadmill exercise and found that in patients with chest pain coronary events were twice as frequent as in individuals with S-T depression alone. The incidence of coronary events was more than twice, if angina was induced by a light work load (4 METS) as compared to when it was induced by a heavy work load.

J point depression (when S-T became isoelectric before 80 m sec) is not a good indicator of coronary disease (lower predictive value) as are horizontal and downsloping patterns of S-T depression so this was not positive response.

Some preliminary studies on abnormal R wave amplitude response were encouraging, but it remained to be seen whether R wave amplitude change would prove to be of value in improving sensitivity, specificity and predictive value of exercise ECG. It is believed by many that an increase in R wave amplitude associated with ischemic S-T changes enhanced the likelihood that a patient with coronary artery disease has extensive involvement, probably associated with left ventricular dysfunction. An isolated R wave amplitude change may allow far greater sensitivity but at the expense of specificity.

In this study seven (10.9%) subjects had abnormal R wave amplitude and in them there was associated S-T depression.

Twelve (18.7%) patients had abnormal blood pressure response ten of them had associated angina. Recognition of this response is not only essential to safely conduct the test, but because the value of this sign as a predictor of critical narrowing of coronary arteries as suggested by a number of reports.

Pontius et al (1978) reported the coronary arteriographic findings of 44 patients in whom systolic blood pressure failed to rise or fall in the absence of other abnormal exercise responses. Of these 44 patients, nine patients had left main coronary artery disease and twenty patients had triple vessel disease. Because of

the poor sensitivity of isolated abnormal blood pressure response (38-75%), it was not included in this study for positive test.

Out of sixty four patients, three (4.7%) had ventricular premature contractions, all the three patients had angina and all of them had S-T depression. By many reports it has been shown that ventricular arrhythmias during exercise testing are common (20% to 72%), being more so in older subjects with coronary disease and have low reproducibility and predictive value for coronary artery disease. The occurrence of these arrhythmias in normal subjects again limits its diagnostic usefulness.

The duration of diabetes has good correlation with severity and incidence of coronary artery disease. In this study, the patients who were diabetic for longer duration had not only higher incidence of coronary artery disease but the disease was more severe in them as compared to these who were diabetic for shorter duration.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present study was carried out in Treadmill Exercise ECG laboratory of Department of Medicine, M.L.B. Medical College, Jhansi. Fortunately none of the patients had any major complications. Though the exercise laboratory was fully equipped to manage any complication during exercise. Sixty four diabetics were selected for the treadmill testing and multivariate analysis was done to draw conclusions. Patients were called for the exercise testing on appointment basis and all the desired instructions were given to them to be followed before and during the test. Guide lines were provided to the patients, regarding treatment, dietary habits and level of physical activity that they should perform safely in future. Informed and written consent was taken from every patient. Preparation of the patients was done with all efforts to get a good quality of tracings because it is the most important factor to interpret the results.

Patients included in this study were from both sexes and from different age groups. The youngest patient was forty three years old and the oldest was of sixty five years. On the basis of their symptoms, majority (65.62%) of patients were from NYHA class I. Coronary risk factors were present in fair number of cases, only seven patients were without any risk factor, except diabetes obviously while others had multiple coronary risk factors.

In some patients the resting heart rate and systolic blood pressure were low while in others these parameters were found at higher side but no correlation was established with the positivity of treadmill. There were three study groups, group I included patients with typical chest pain suggestive of angina pectoris and comprised of twelve patients, group II included patients with atypical chest pain probably of non-ischemic origin and comprised of sixteen patients. While group III comprised of thirty six patients. It was important to note that incidence of I.H.D. was maximum in group I and minimum in group III. During exercise, shift of S-T segment was variable in different patients, but considering all the three study groups together maximum number of subjects had two mm or more S-T segment depression. Chest pain was very important event during the stress testing. In group III patients, only few had chest pain when doing treadmill while S-T segment depression was present in many cases probably indicating silent myocardial ischemia. Abnormal ECG and non ECG findings were present in variable number of patients.

The number of risk factors had good correlation with positivity of the treadmill, the later being higher with increasing number of risk factors in an individual. NYHA classes also had good relationship with positivity of treadmill. The later increasing with higher NYHA

class. METS achieved by the patients during exercise was also an indicator of severity of disease. positivity of TMT being inversely proportional to the number of METS achieved.

Patients with strongly positive test were found to have achieved low pressure products and exercised for a shorter period as compared to those having milder changes in exercise test.

The conclusions based on the data obtained by treadmill testing were as follows :-

1. This study was conducted in 64 subjects ranging from age 43 years to 65 years (average 51.7 years). Out of these fifty two were males and twelve females.
2. Out of the sixty four subjects, forty two males had positive treadmill test and eight females were also positive. In males treadmill was positive in 80.7% cases while in females it was positive only in 66.7% cases. Thus the difference, as expected, being diabetes, was not too much.
3. Risk factors were present in fair number of cases, three patients had three risk factors each, fifteen had two each while in thirty nine patients, there was only one in each case. Seven patients were without any risk factors. Hypertension, which was the commonest risk factor being present in 37.5% subjects, was also found to be associated with higher incidence of positive TMT cases. TMT was positive in

all the cases having three risk factors each. Average number of risk factors was 1.2 present (N.B.. Since all the subjects were diabetic so infact the average risk factors were 2.2).

4. Probability of positive TMT increases with increasing duration of diabetes. Patients who had diabetes for less than five years had 62.5% positive TMT, in ten years' diabetics it was 79.3% and those who were diabetic for more than ten years had positive TMT in 89.5% patients.

5. The average resting heart rate was 84 per minute and the systolic B.P. was 144 mm Hg. This did not have any bearing on TMT results.

6. Prevalence of CAD was directly related to the nature of symptoms :

- Subjects with typical chest pain had higher prevalence of positive tests, out of twelve patients of this group all were treadmill positive.
- Subjects with atypical chest pain of probable ischemic origin had 85.5% prevalence of positive test (fourteen out of sixteen).
- In atypical chest pain probably of non ischemic origin the possiblity of CAD was still less, out of thirty six patients twenty four had positive treadmill.

7. Onset of S-T depression had direct correlation with positivity of TMT. In 32% cases S-T segment depression started in stage one of modified Bruce protocol and these patients were found to have strongly positive TMT.

8. Chest pain was a significant finding during treadmill testing. Out of thirty six patients with atypical chest pain probably of non-ischemic origin, twenty four had positive treadmill test. Of these positive cases only seven had chest pain during exercise and in seventeen myocardial ischemia was silent.

9. Abnormal B.P. finding during exercise was a very common findings and in majority it is associated with positive treadmill test.

10. There was direct correlation of severity of CAD with functional class. Those subjects having symptoms of functional class II and III had more prevalence of CAD. Correlation of severity of CAD to the total METS achieved was similar.

11. Double product achieved by patients was inversely proportional to the severity of CAD. Less was the double product achieved more was the severity of CAD.

The present study has shown that the incidence of CAD as documented by positive TMT exercise testing is definitely higher as compared to non-diabetics irrespective of type of chest pain.

To conclude the treadmill exercise ECG testing seems a good screening test for diabetics to unearth asymptomatic myocardial ischaemia and to document/ exclude the same in diabetics having atypical chest pain seemingly of non-ischaemic origin. Treadmill stress test also seems a fruitful guide to prescribe physical exercise to diabetics within safe limits, so that diabetics are not prey to the on slaught of silent myocardial ischaemia.

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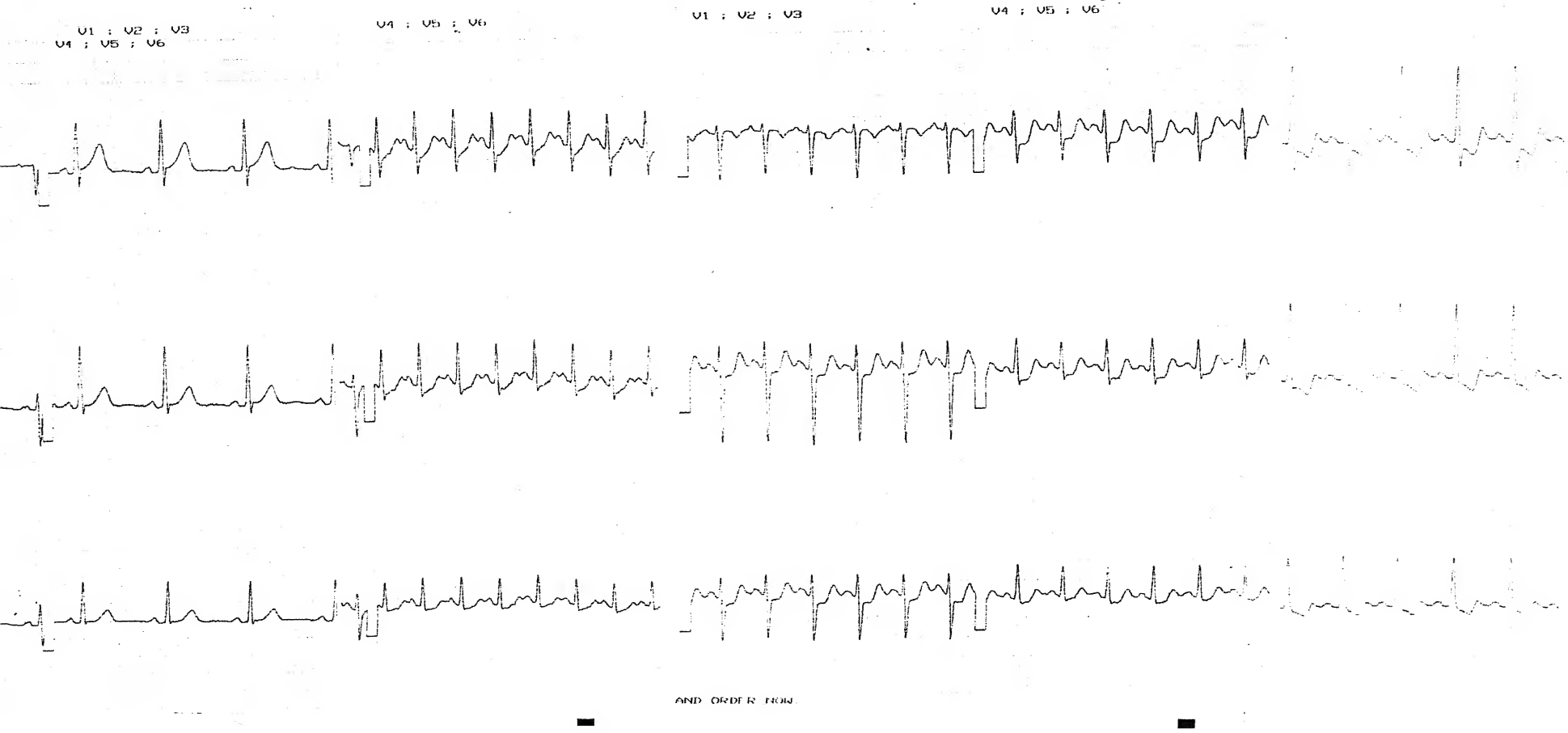
A P P E N D I X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ट्रेडमिल स्ट्रैस टेस्ट के लिये आवश्यक निर्देश :

1- जाँच के दिन सी0सी0यू0 कक्ष में निर्धारित समय पर आयें।

2- जाँच से कम से कम दो घण्टे पहले हल्का नाश्ता करके आयें। नाश्ते में काफी, तम्बाकू, चाय आदि न लें।

3- मरीज के साथ एक अभिभावक का होना आवश्यक है। अन्यथा जाँच नहीं हो पायेगी।

4- स्त्रियाँ पूरी सलवार पहन कर आयें।

5- ट्रेडमिल जाँच से पहले जो दवायें न लेने का निर्देश चिकित्सक ने दिया है उसका ठीक प्रकार से पालन करें। दवा न लेने से यदि कोई परेशानी हो तो तुरन्त चिकित्सक से परामर्श करें।

6- दिल की बीमारी से सम्बन्धित सभी रिपोर्ट्स जैसे ई0सी0जी0 आदि अपने साथ ले कर आयें।

प्रभारी अधिकारी,
हृदय रोग केन्द्र।

सहमति पत्र

मरीज का नाम : उम्र :

ओ0पी0डी0/एम0आर0डी0 नं0 :

चिकित्सक का नाम :

मैं अपनी/अपने मरीज के दिल की जाँच (ट्रेडमिल स्ट्रैस टेस्ट) कराने को तैयार हूँ। इस टेस्ट तथा इसके करने से होने वाले खतरों से मुझे भलीभाँति अवगत करा दिया गया है। जिसकी जिम्मेदारी मेरी अपनी होगी। मैं टेस्ट की पूर्ण सहमति देता हूँ।

मरीज/अभिभावक के हस्ताक्षर

दिनांक:

साक्षी :

मरीज से सम्बन्ध :

पता :

DEPARTMENT OF MEDICINE, M.L.B. MEDICAL COLLEGE, JHANSI

PROFORMA FOR TREADMILL TESTING

OPD/MRD No. _____ Sl. No. _____

1. Name
2. Age/Sex
3. Address
4. Marital Status : Single/married
5. Socio-economic status :
6. Name of occupation
7. Level of Activity : Active/Sedentary :
8. Reffered by :

HISTORY :

Chief Complaints : 1.
2.
3.

HISTORY OF PRESENT ILLNESS

Chest Pain :
a. Duration
b. Site
c. Character
d. Radiation
e. Precipitating Factors
f. Relieving Factors
g. Frequency

Dyspnoea
- Exertional dyspnoea - Duration
  - Grade
- PND
- Orthopnoea
- Pulmonary oedema

Palpitation - Duration

- Nature - Continuous
- Paroxysmal - Polyurea
  - Sweating
  - Chest pain
  - Syncope
  - Others

Cough - Duration

- Nature — Dry — Productive
- Timing

Haemoptysis - Duration

- Frequency

Syncope

Other symptoms

PAST HISTORY

Whether suffering/suffered from following diseases:

1. Rheumatic fever — H/o Cardiac Surgery
2. Hypertension
3. Diabetes
4. Tuberculosis
5. Gout
6. Hyperlipidaemia
7. Other Specify

PERSONAL HISTORY

Vegetarian — Non-vegetarian

Smoking — Duration

Amount

Alcohol

FAMILY HISTORY

IHD.

Hypertension

Diabetes

If yes, state age, relationship :

HISTORY OF DRUG INTAKE

Specify name, dose, duration of drugs

PHYSICAL EXAMINATION

Weight kg Height cms

Pulse per min.

B.P. :

Upper limb : Systolic Diastolic

Lower limb : Systolic Diastolic

Resp. rate Cyanosis

Clubbing Oedema

Icterus Pallor

Lymph Nodes Hydration

Xanthelasma/Xanthoma

CVS EXAMINATION

Inspection

Palpation

Auscultation Ist Sound IInd Sound Accompaniments

Mitral Area

Aortic Area

Pulmonary Area

Tricuspid Area

Resp. Sysrem Examination

CNS Examination

Abdomen.

INVESTIGATION

Haematological

Hb gm TLC :

DLC : P L E M B

ESR.

Serum Cholesterol STG HDL

Blood Sugar : Fasting PP

Urice Acid

Blood Urea S. Creatinine

X-Ray Chest

E.C.G.

Report of any other investigations

TMT/CART/Coronary Angiography/Holter

PROFORMA FOR EXERCISE TESTING

Sl.No. ______ Dated :

Informed Consent :

Indication

Protocol Used

Sign & Symptoms :

	HR	BP	Arrhyth-mias	ST changes	Sign/ Symptoms	R wave in V_5
Supine						
Standing						
Hyperven-tilation (2 mts).						

Stage	Time in stage (mts.)	Total time (mts)	B.P.	HR	Arrhy-thmias	S-T changes	Symp/ Sign	'R' wave

~~XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX~~

RECOVERY

1. Predicted Max Heart Rate :

 90% of Max HR

 85% of Max HR

2. Heart rate achieved

3. Total duration of Exercise METS

4. Functional Aerobic Impairment

5. Double Product

6. Sign of LV failure.

INTERPRETATION

Summary of aonormal findings and their significance.

RESULT

ADVICE

FOLLOW UP TMT

Date Sl No.

Interpretation

Reported by TMT INCHARGE

CARDIOLOGIST